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# (12) United States Patent
**Inoue**

(10) **Patent No.: US 6,785,005 B2**
(45) **Date of Patent: Aug. 31, 2004**

(54) **SWITCHING TYPE DUAL WAFER STAGE**


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(73) Assignee: **Nikon Corporation**, Tokyo (JP)



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(22) Filed: **Sep. 21, 2001**

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(52) **U.S. Cl.** ....................................................... **356/500**
(58) **Field of Search** ................................ 356/486, 487, 356/493, 496, 498, 500; 250/559.29, 559.3


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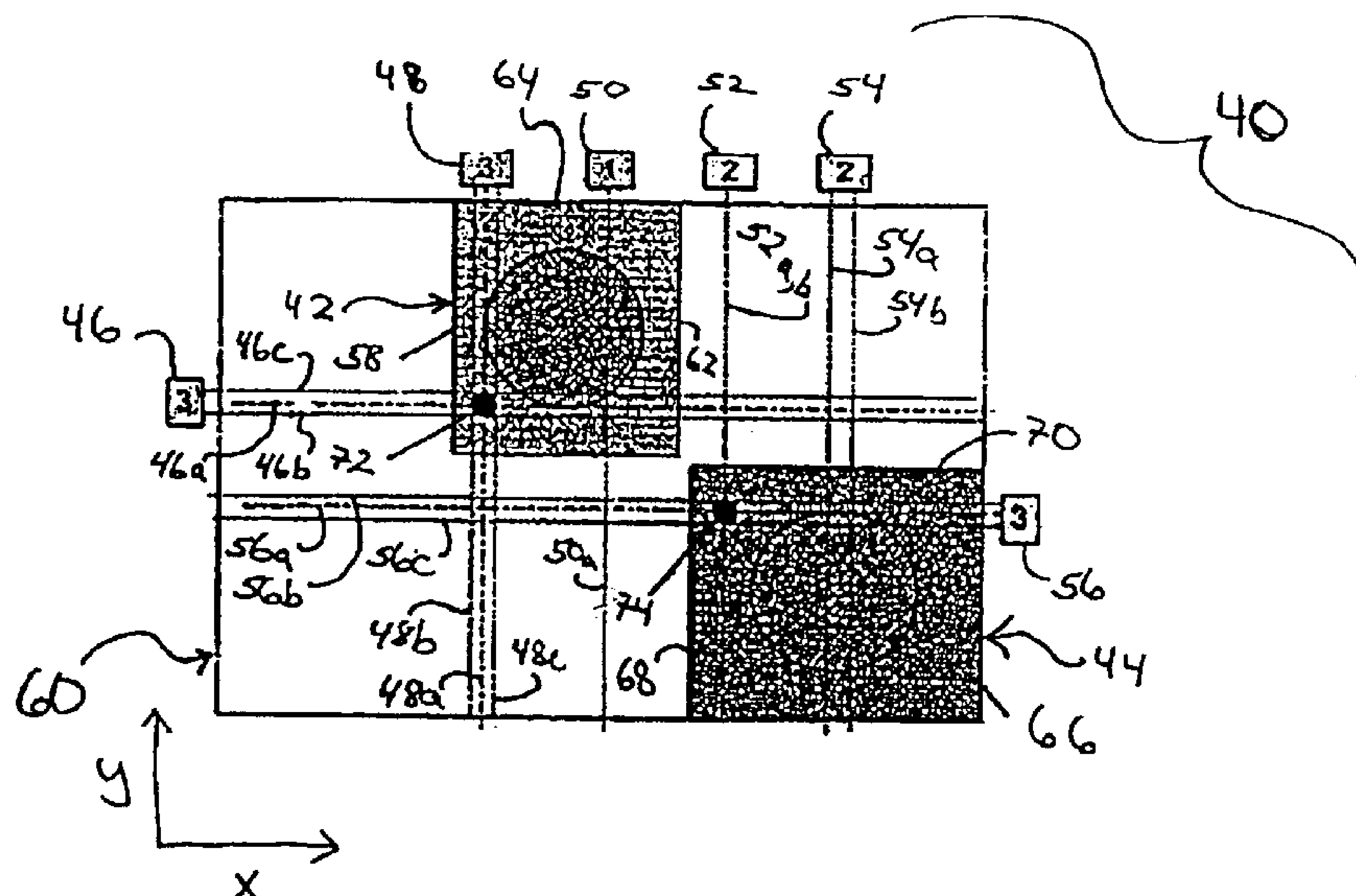
(57) **ABSTRACT**


This invention relates to an apparatus and method for positioning dual stages during semiconductor wafer processing. More particularly, the invention facilitates the use of interferometers to determine the positions of both wafer stages at all times during processing. While the movement of a typical twin stage apparatus causes one of the stages to eclipse the other and requires the addition of a significant number of additional interferometers, this invention minimizes the number of interferometers necessary through dimensioning the stages so that one stage never totally eclipses the other.


**28 Claims, 26 Drawing Sheets**



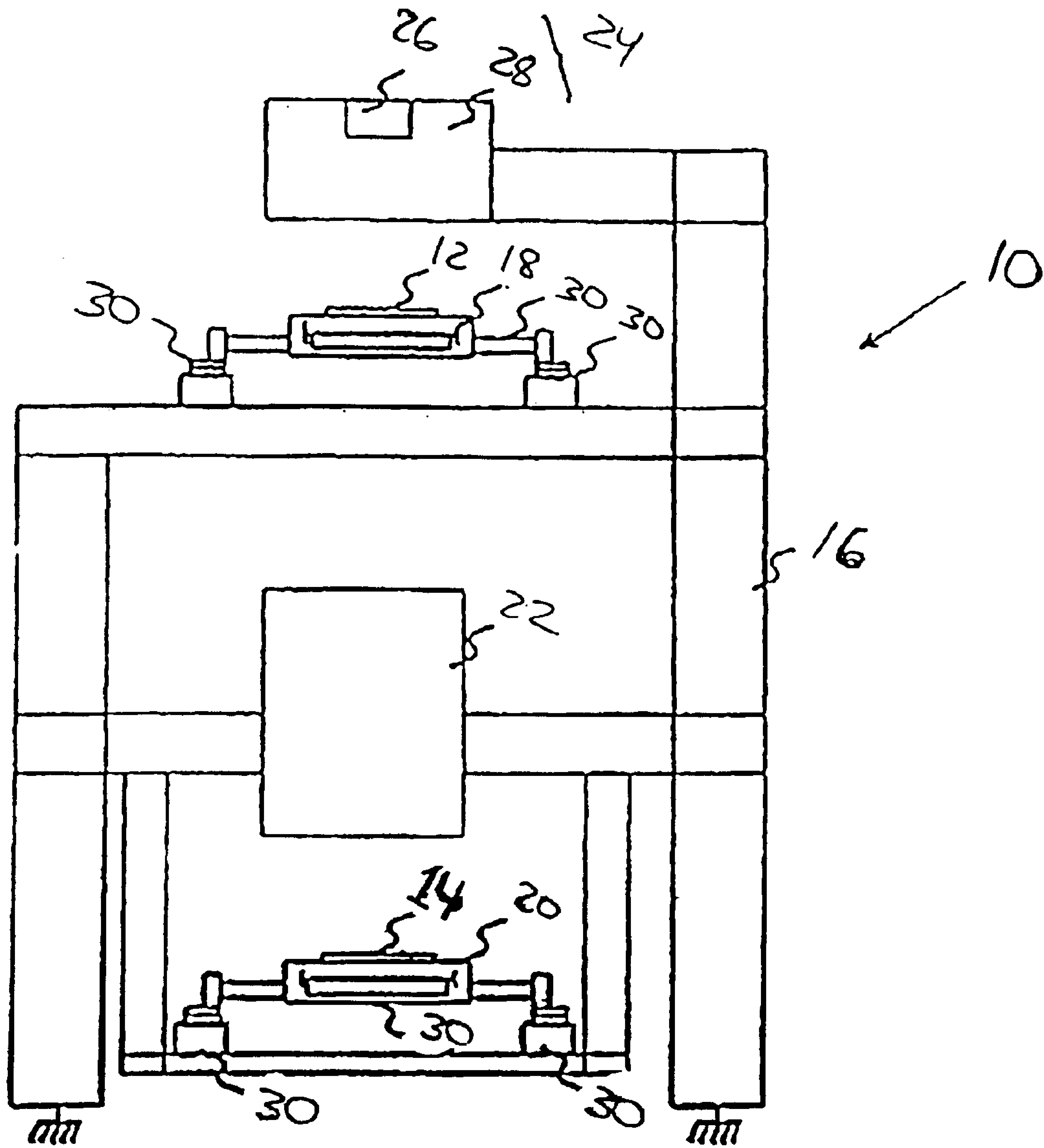



FIG. 1
PRIOR ART

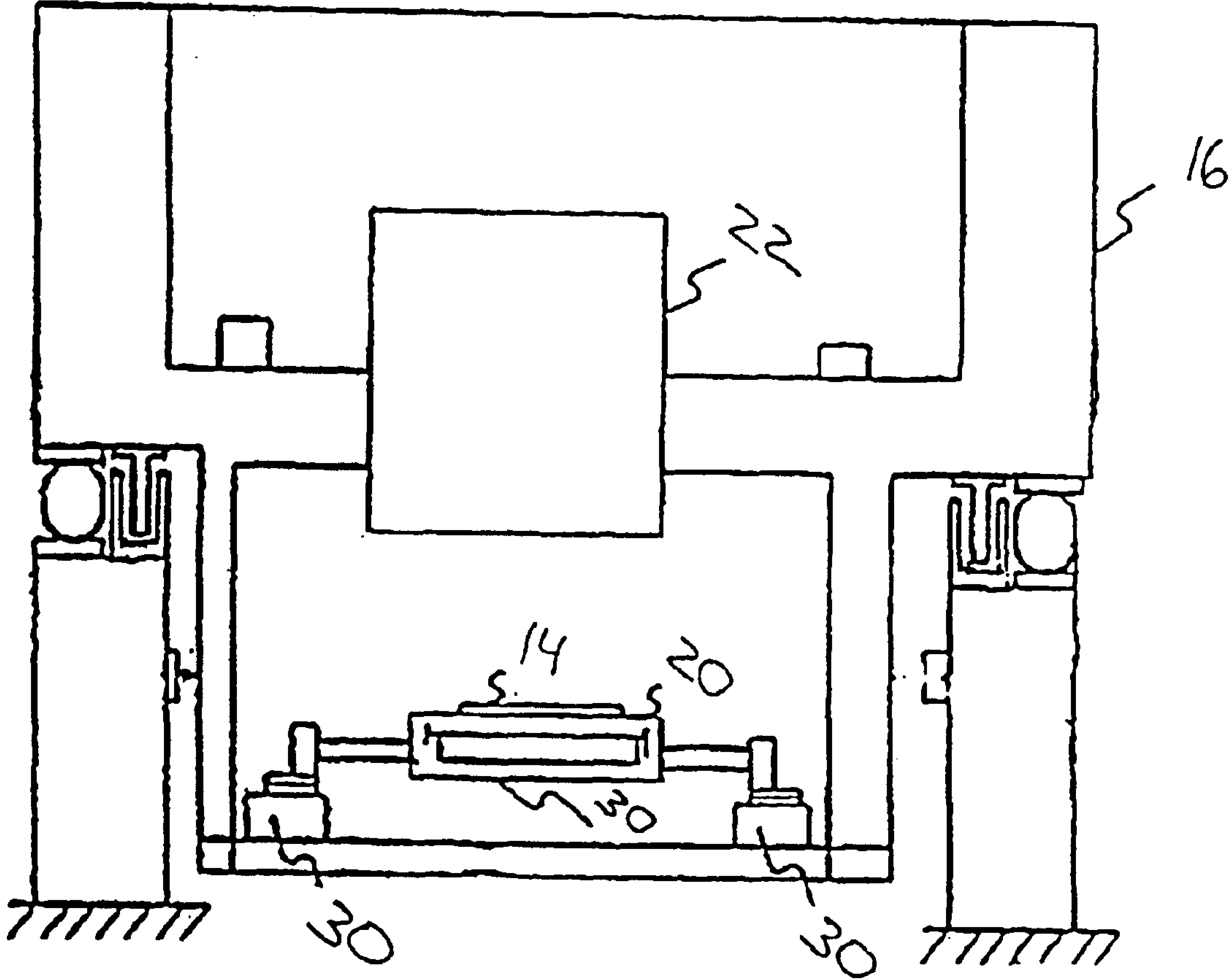



FIG. 2
PRIOR ART

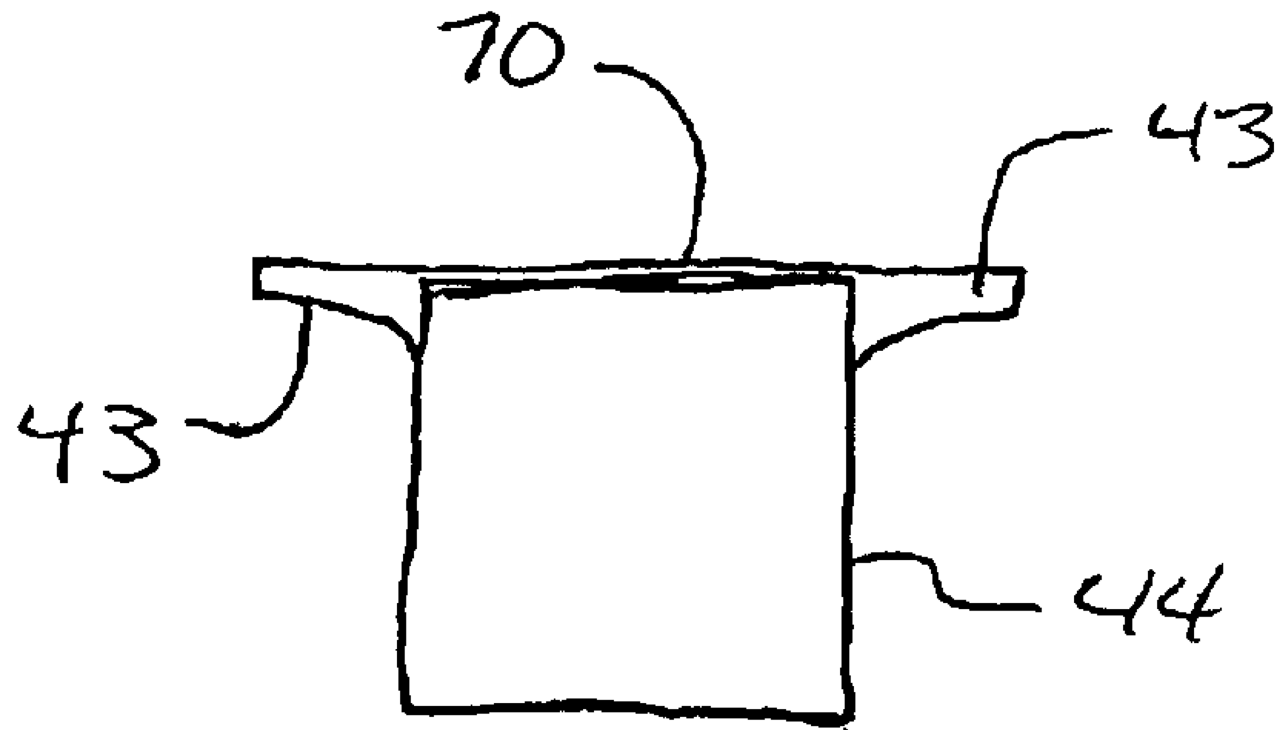



FIG. 3(A)

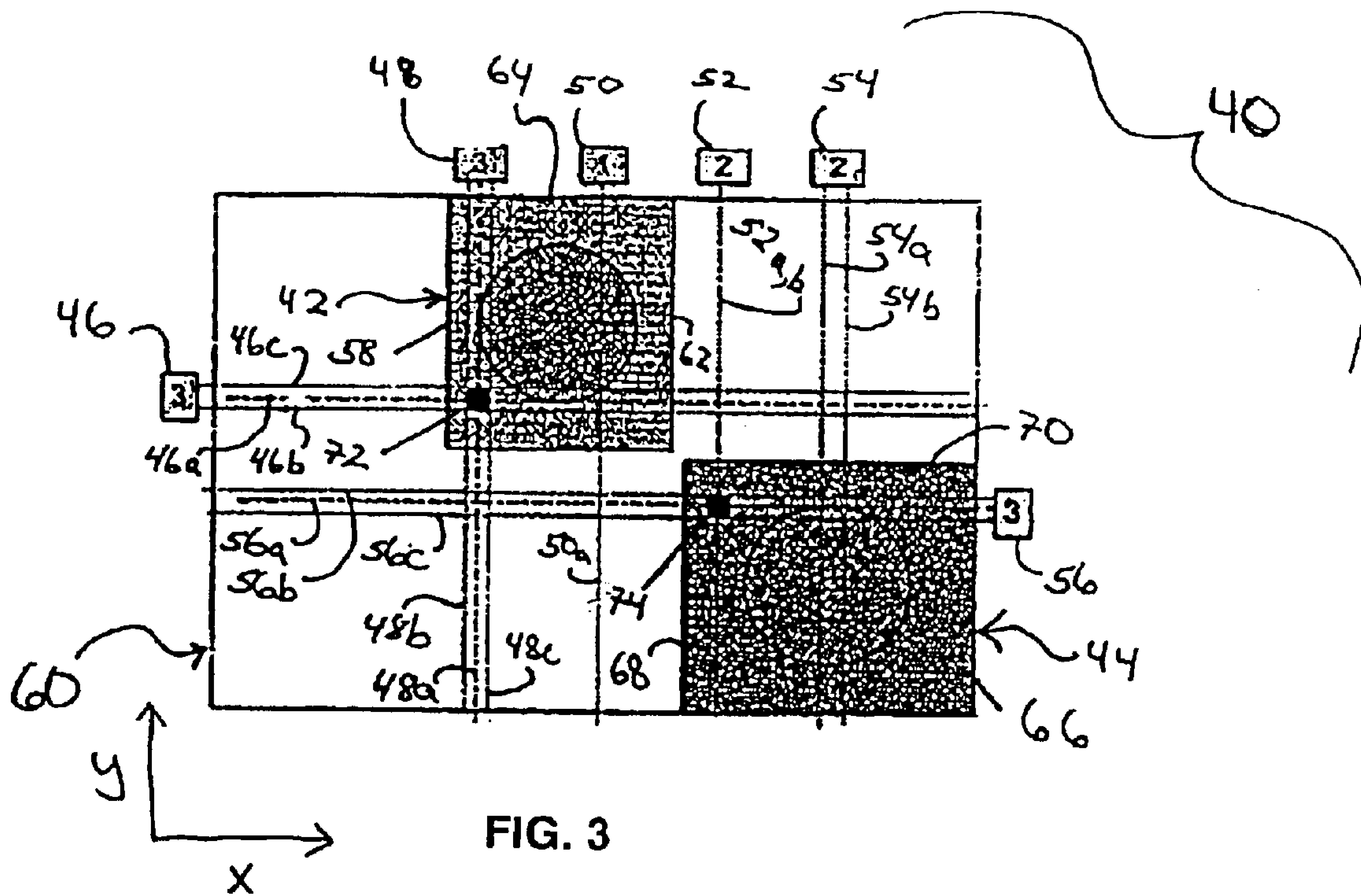



FIG. 3

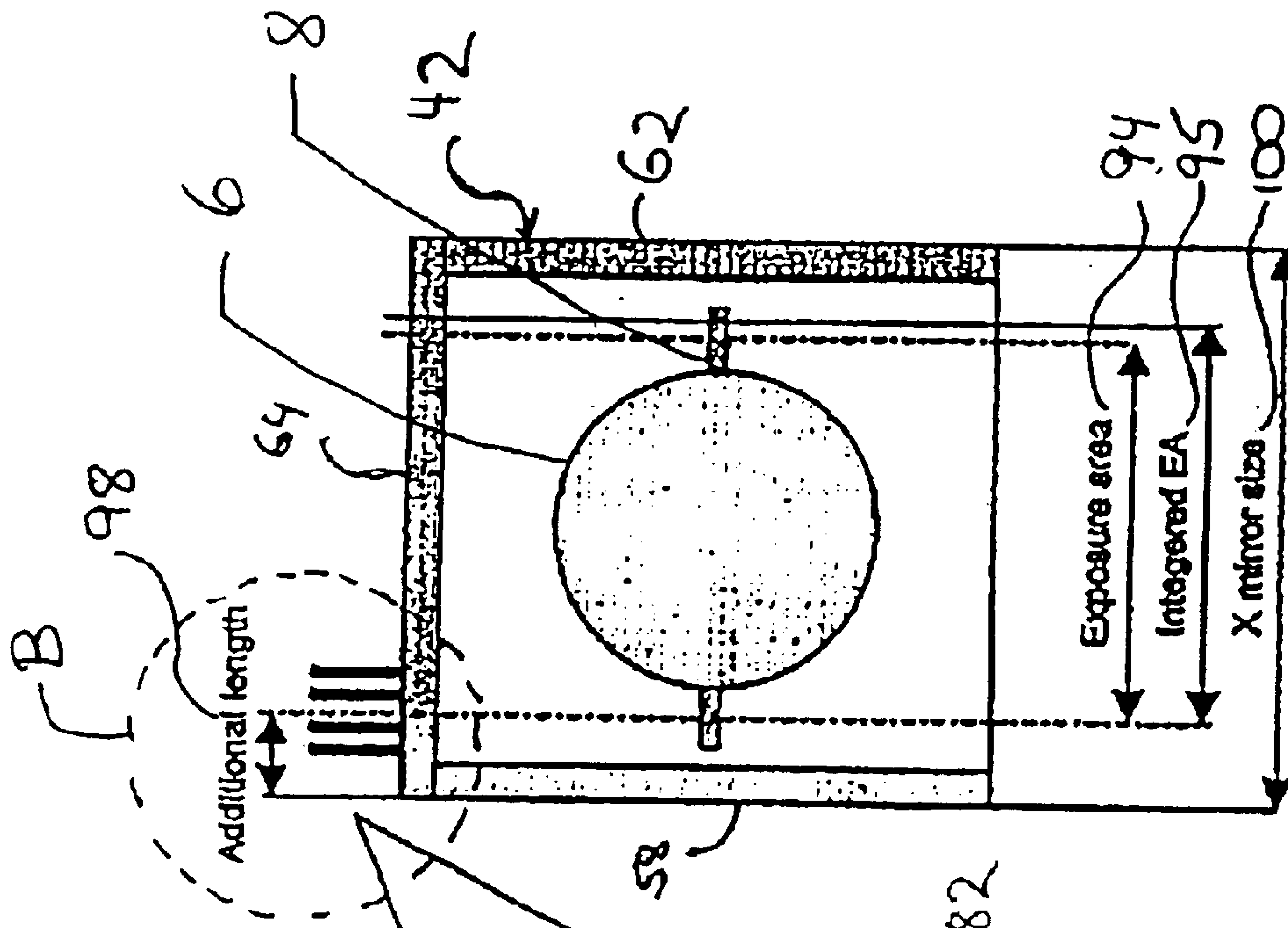



FIG. 4(A)

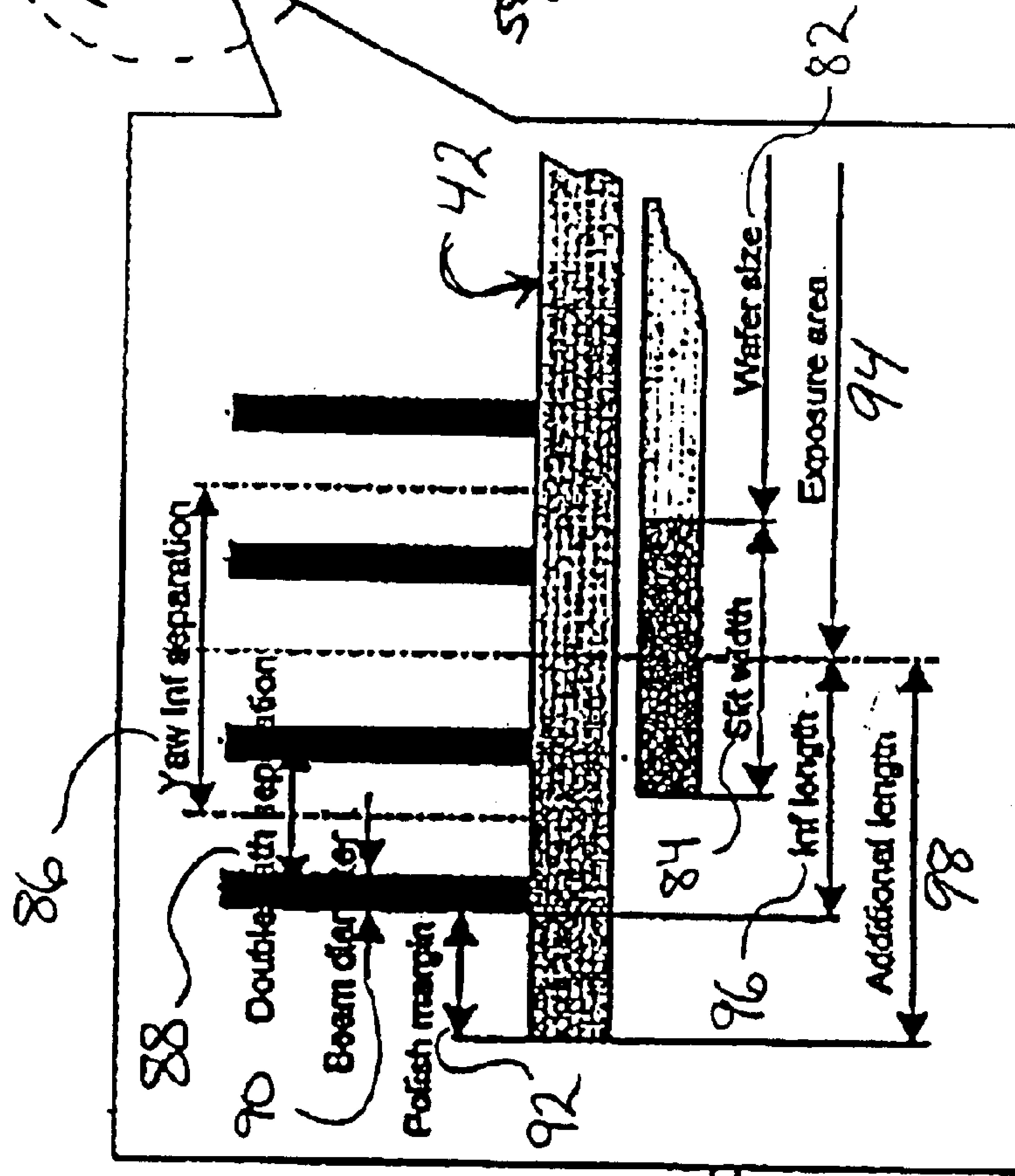



FIG. 4(B)

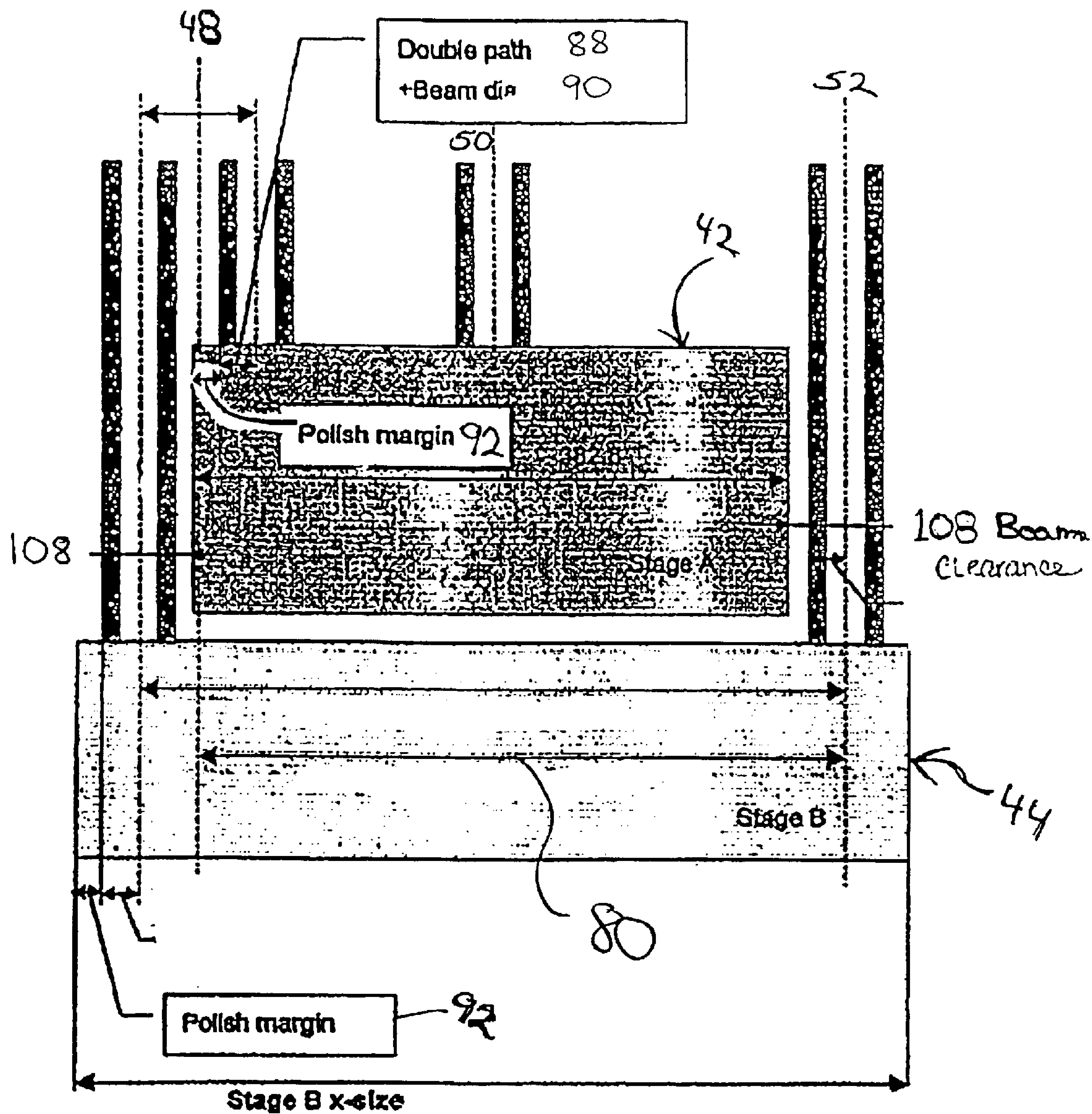



FIG. 5

FIG. 6



FIG. 7

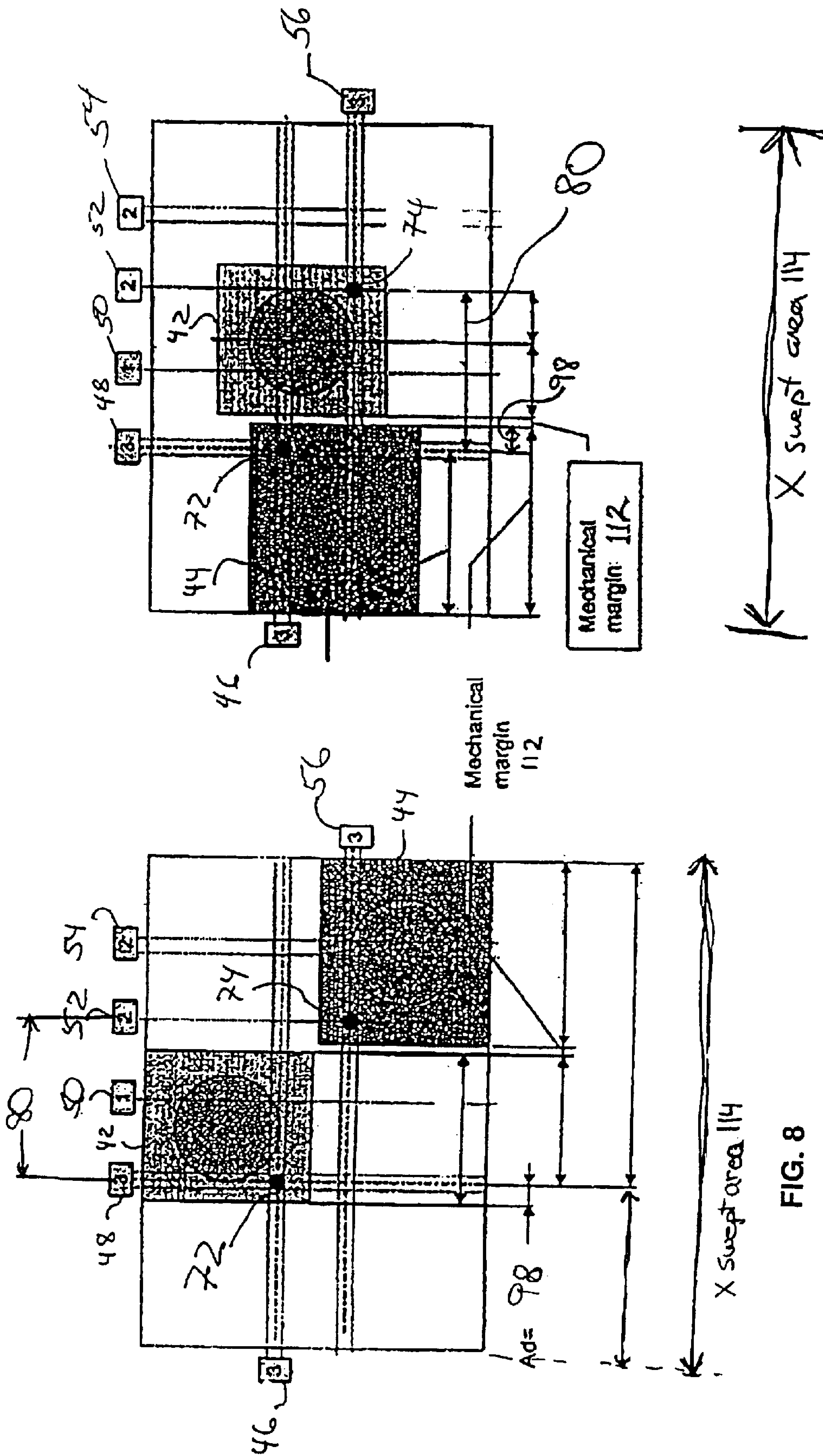



FIG. 9

FIG. 8

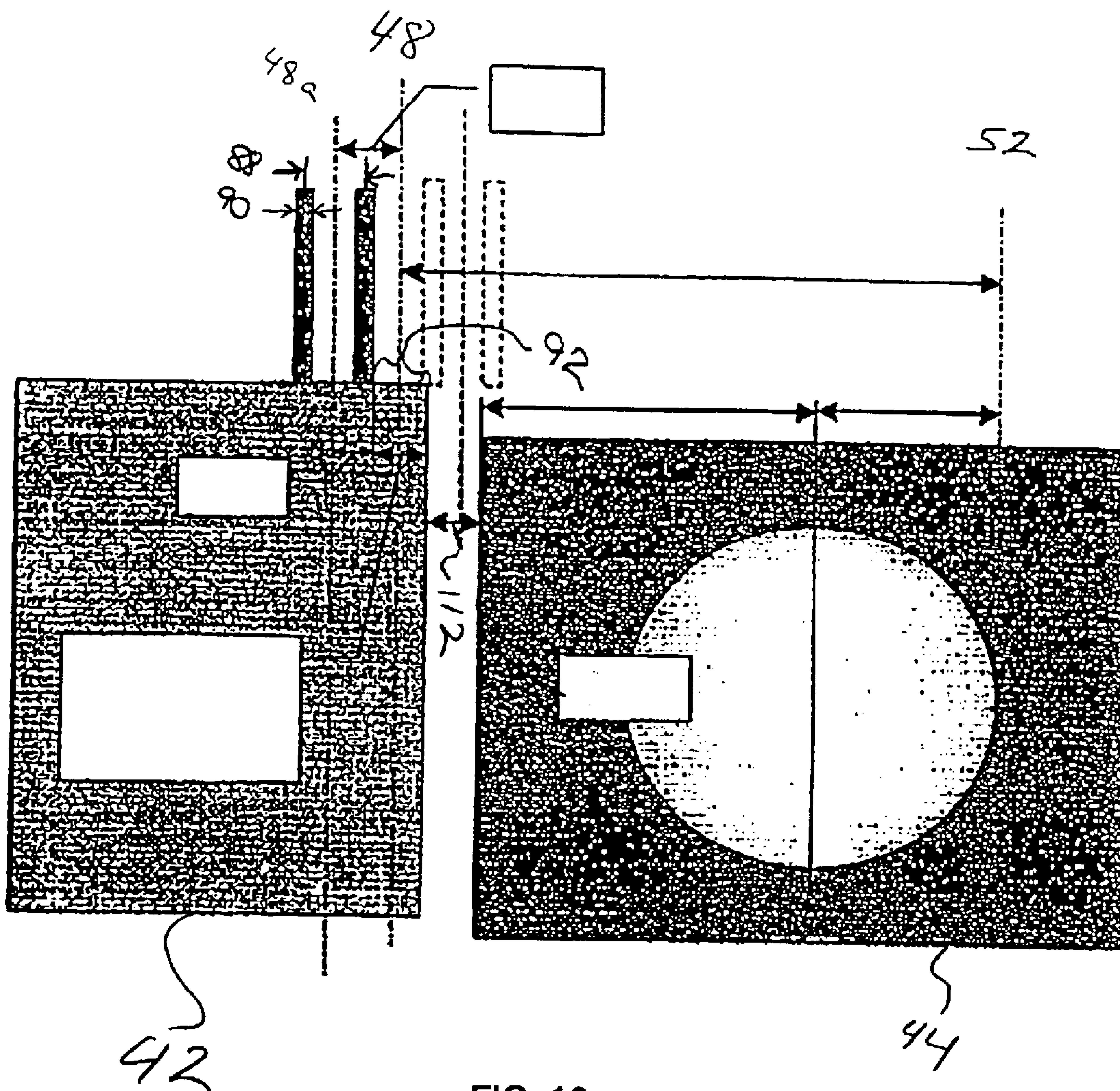



FIG. 10

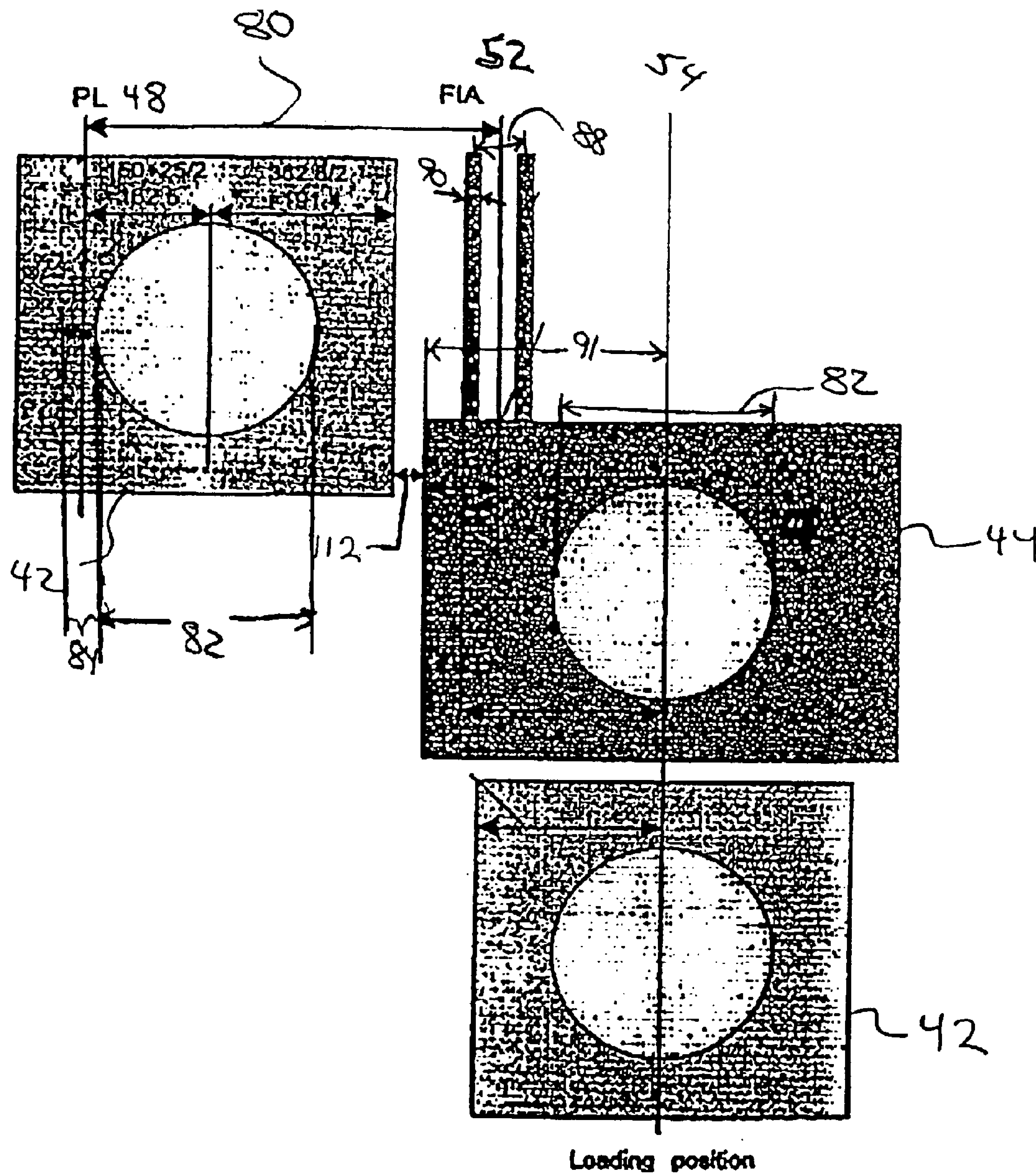



FIG. 11

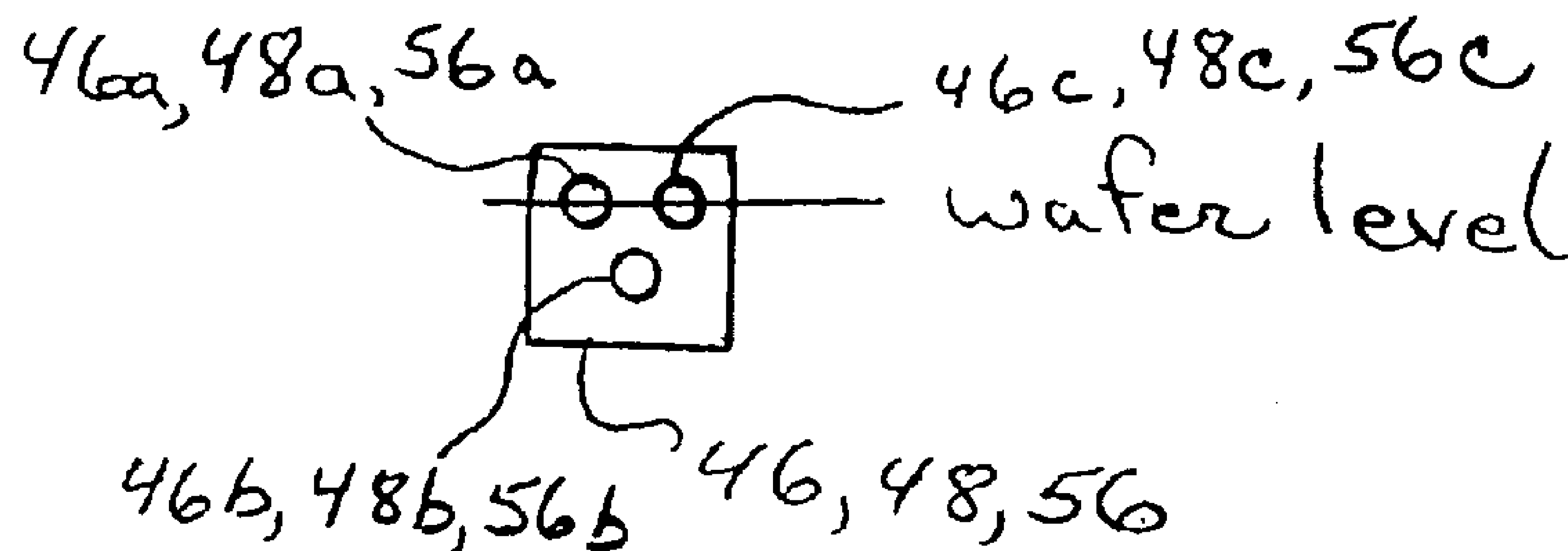



FIG. 12(A)

FIG. 12(B)

FIG. 12(C)

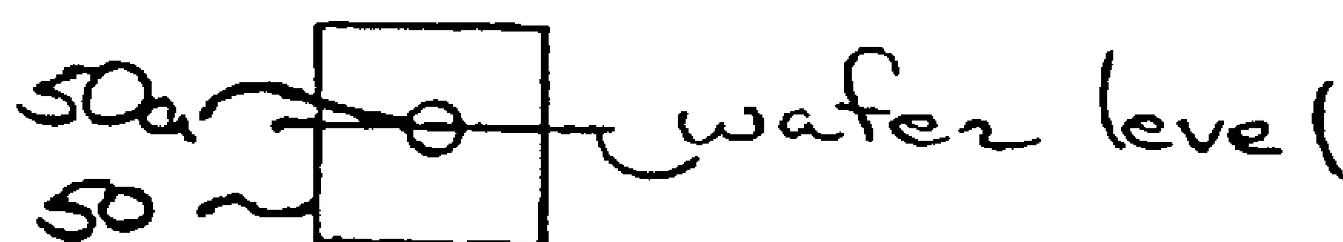



FIG. 12(D)

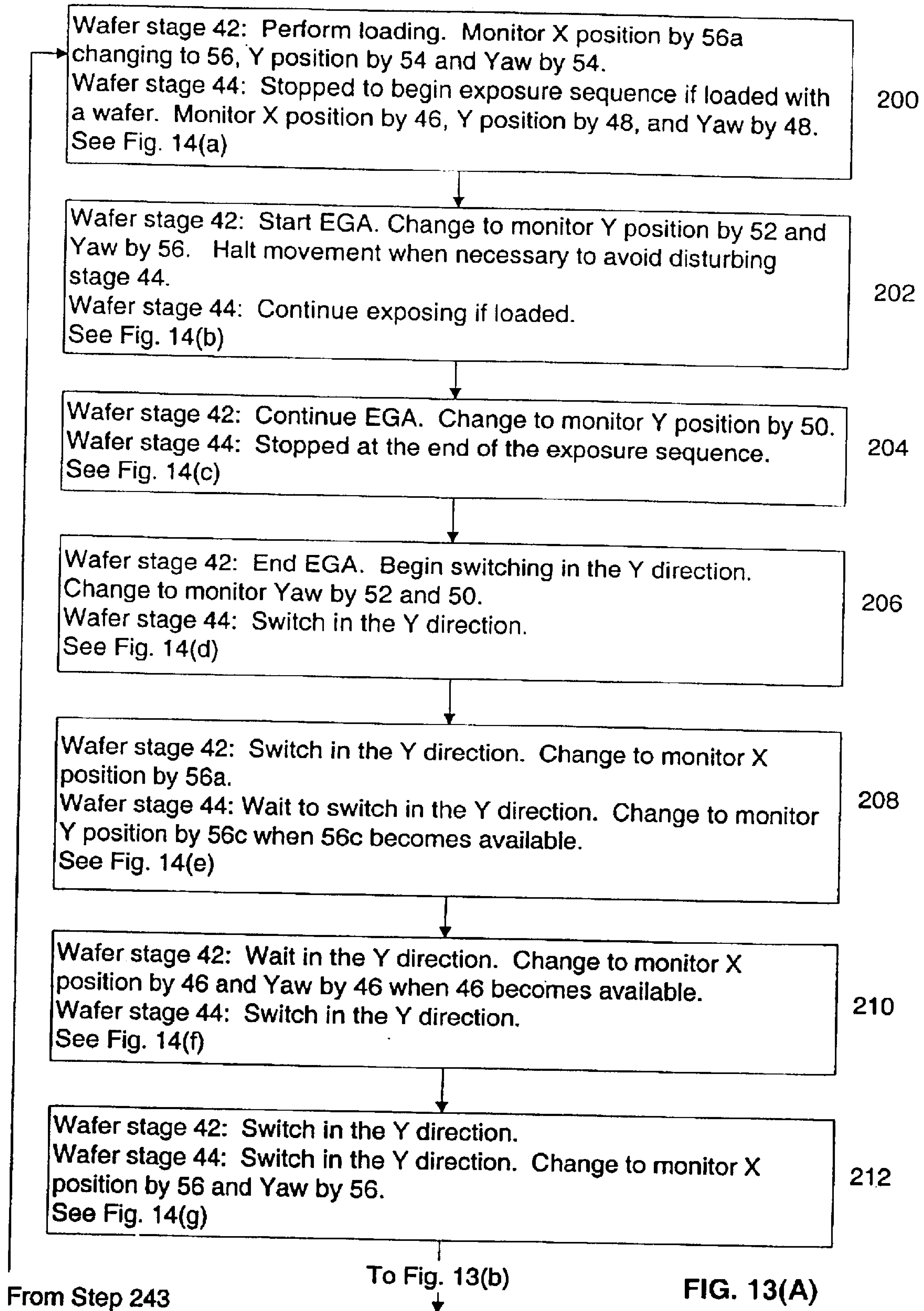



FIG. 13(A)

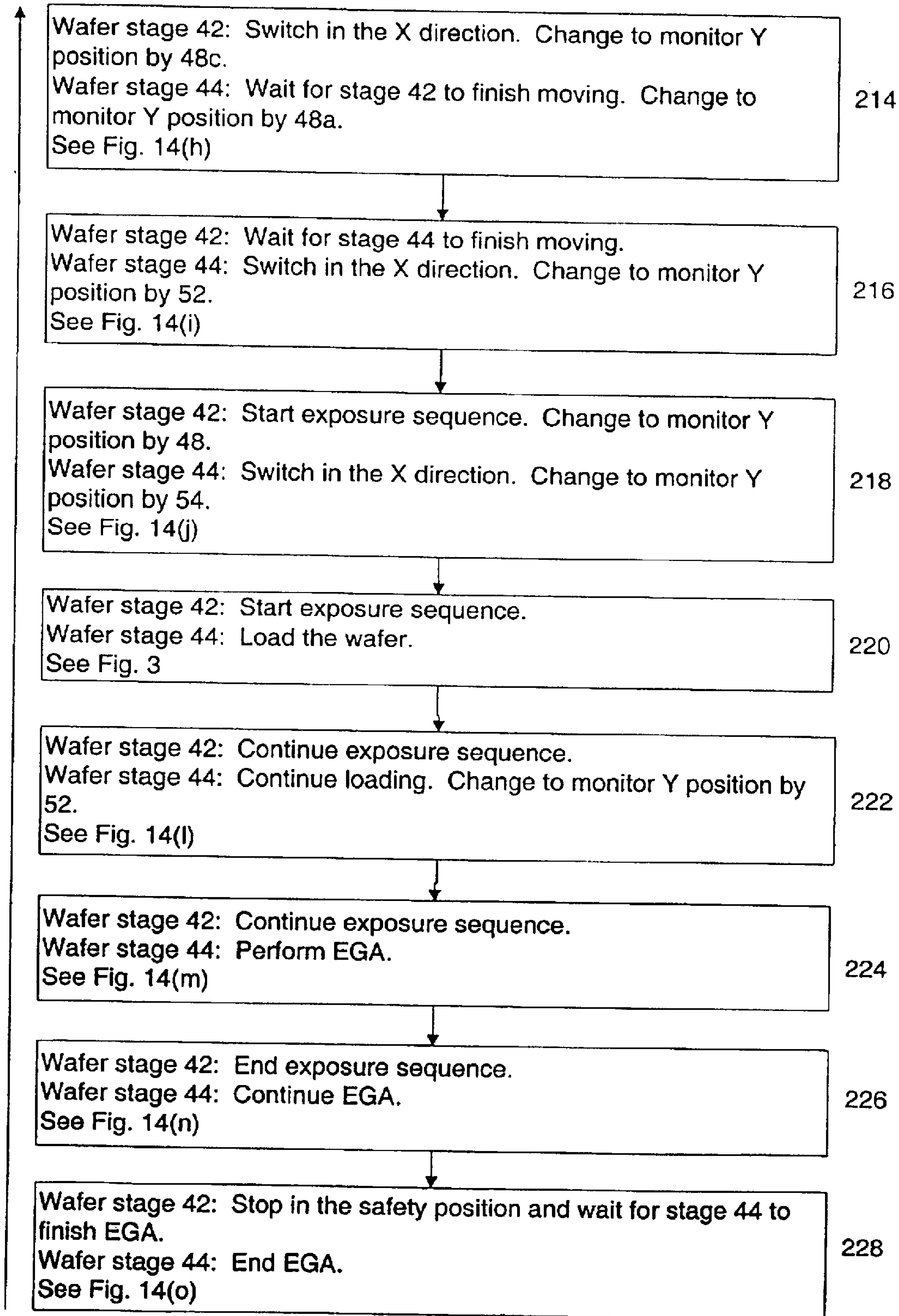



FIG. 13(B)

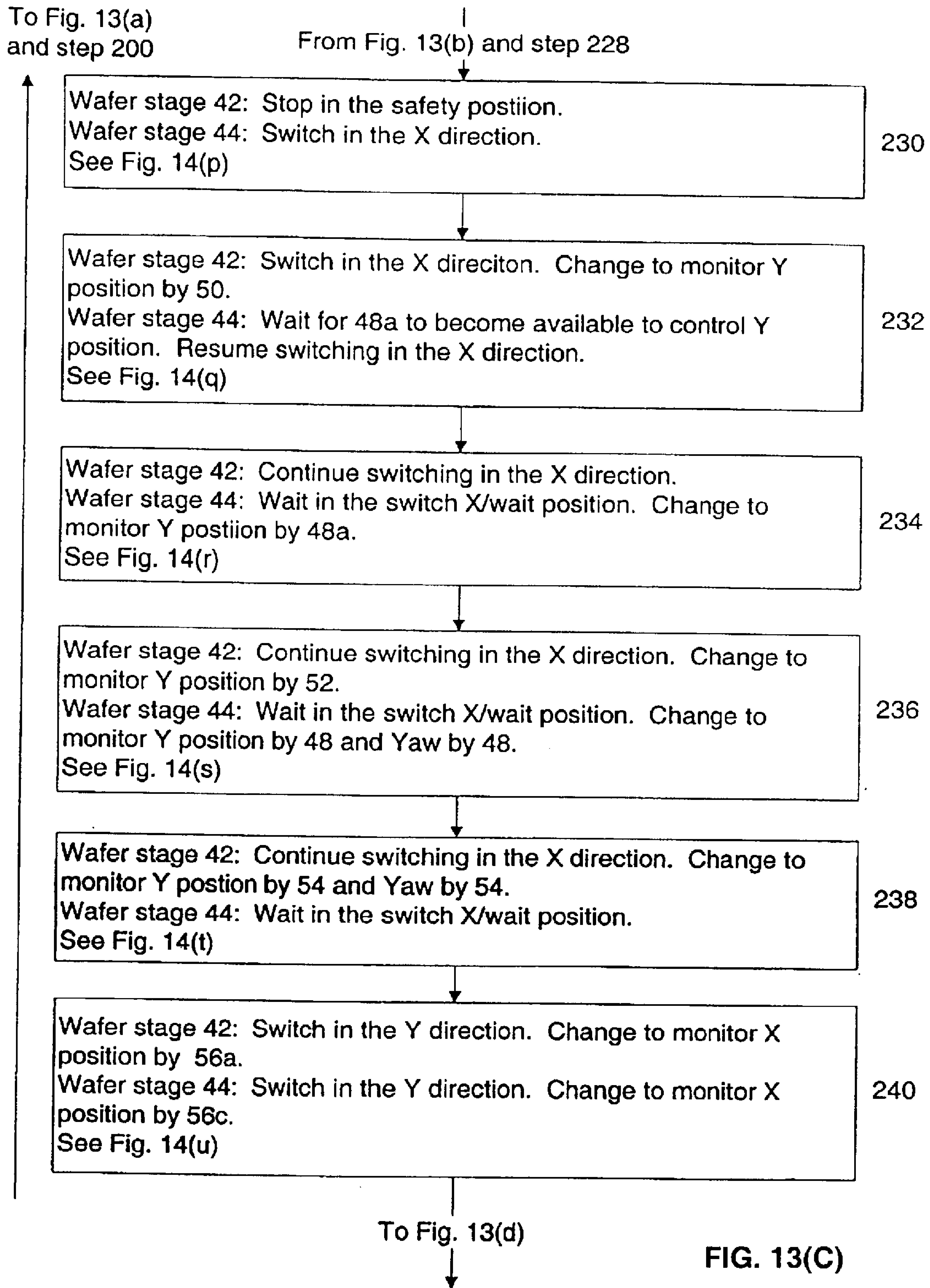



FIG. 13(C)

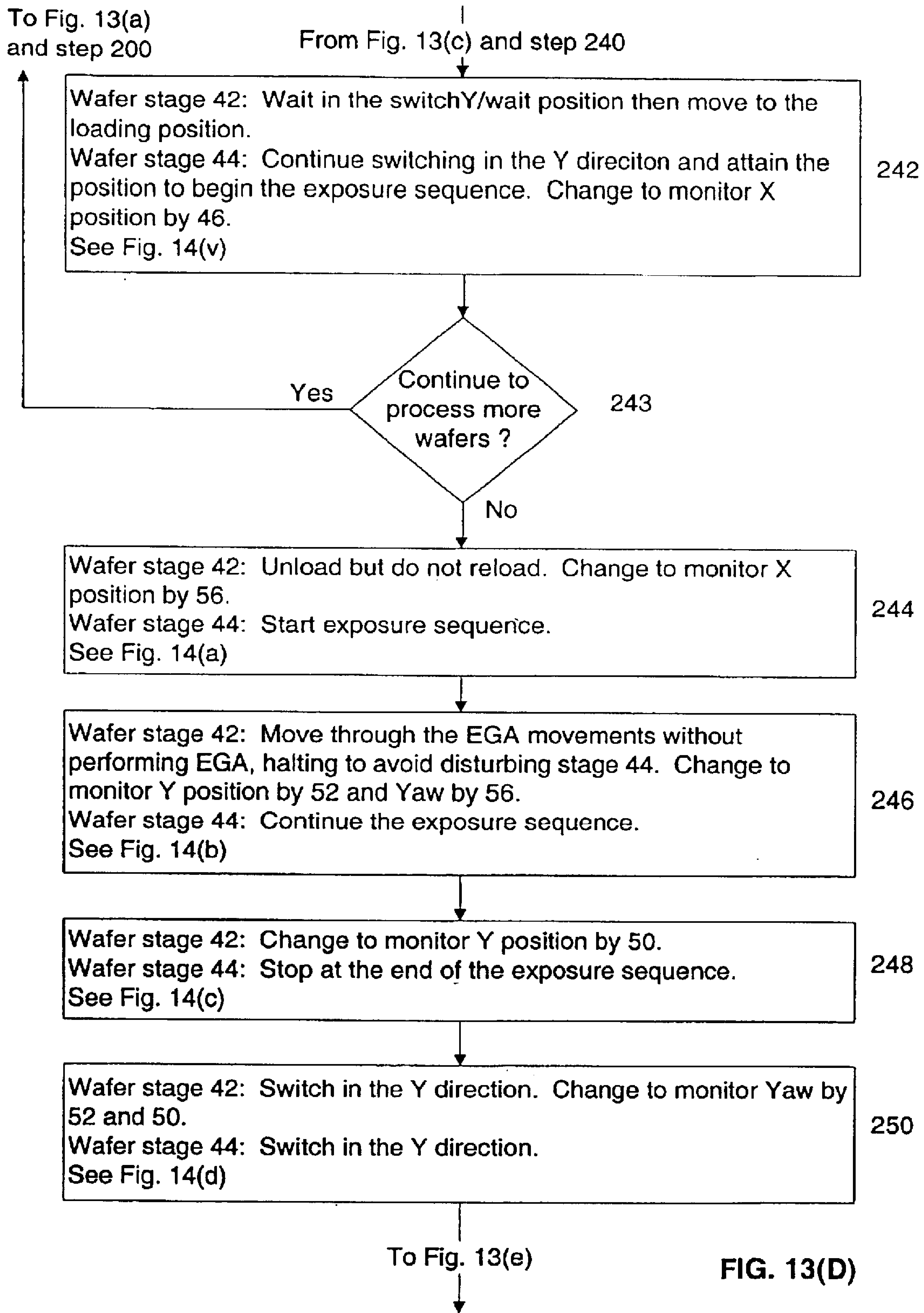



FIG. 13(D)

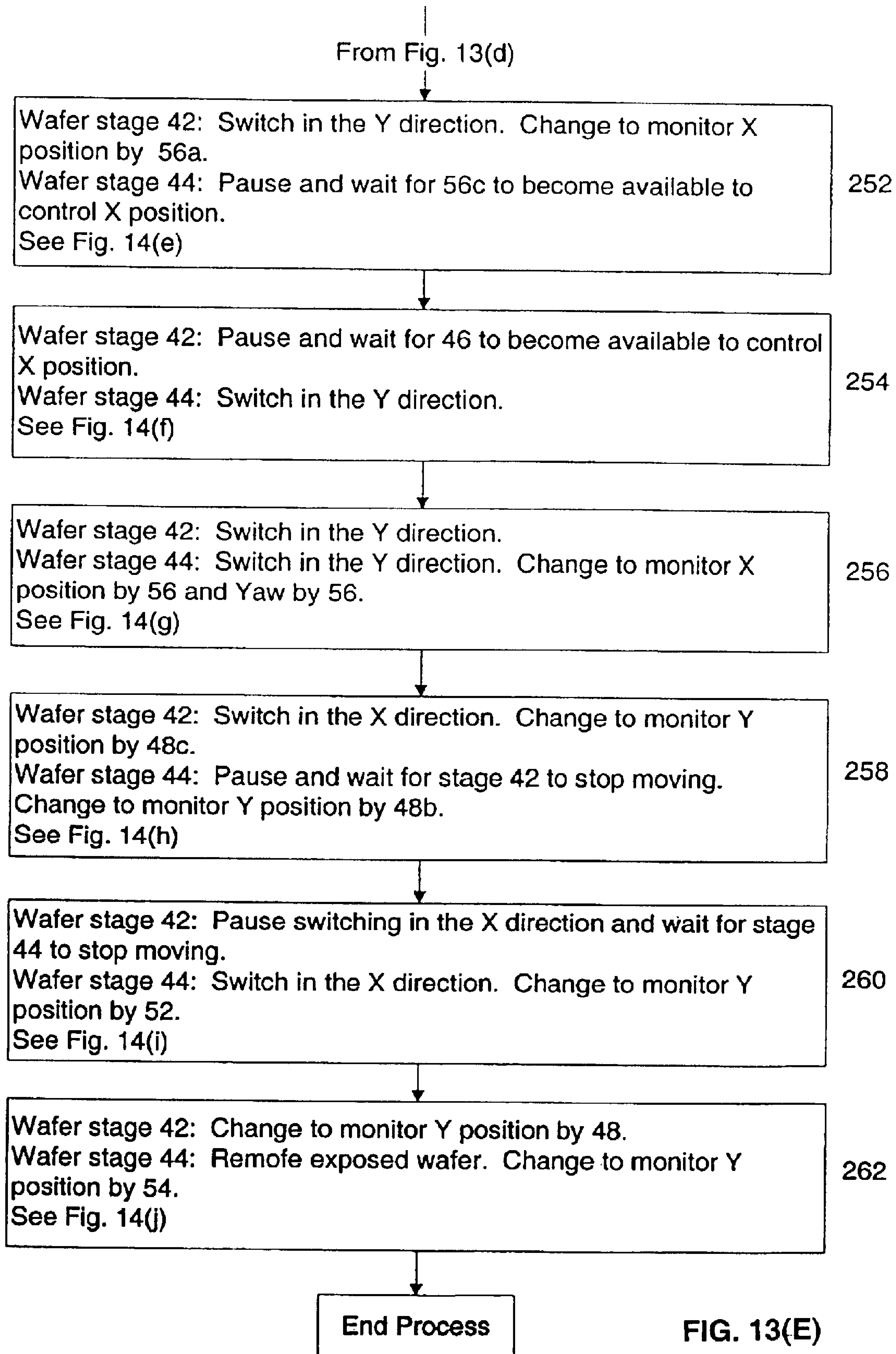



FIG. 13(E)

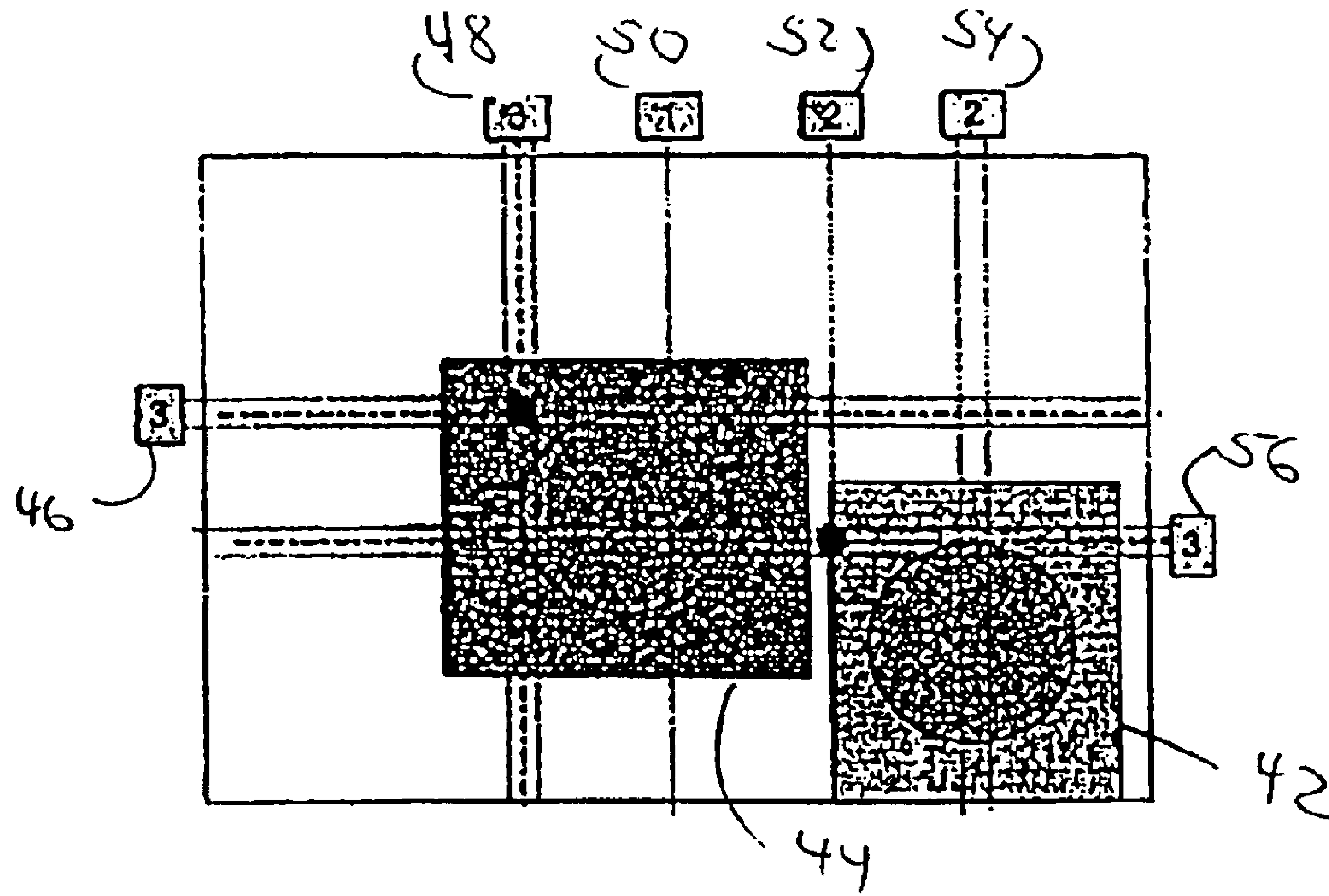



FIG. 14(A)

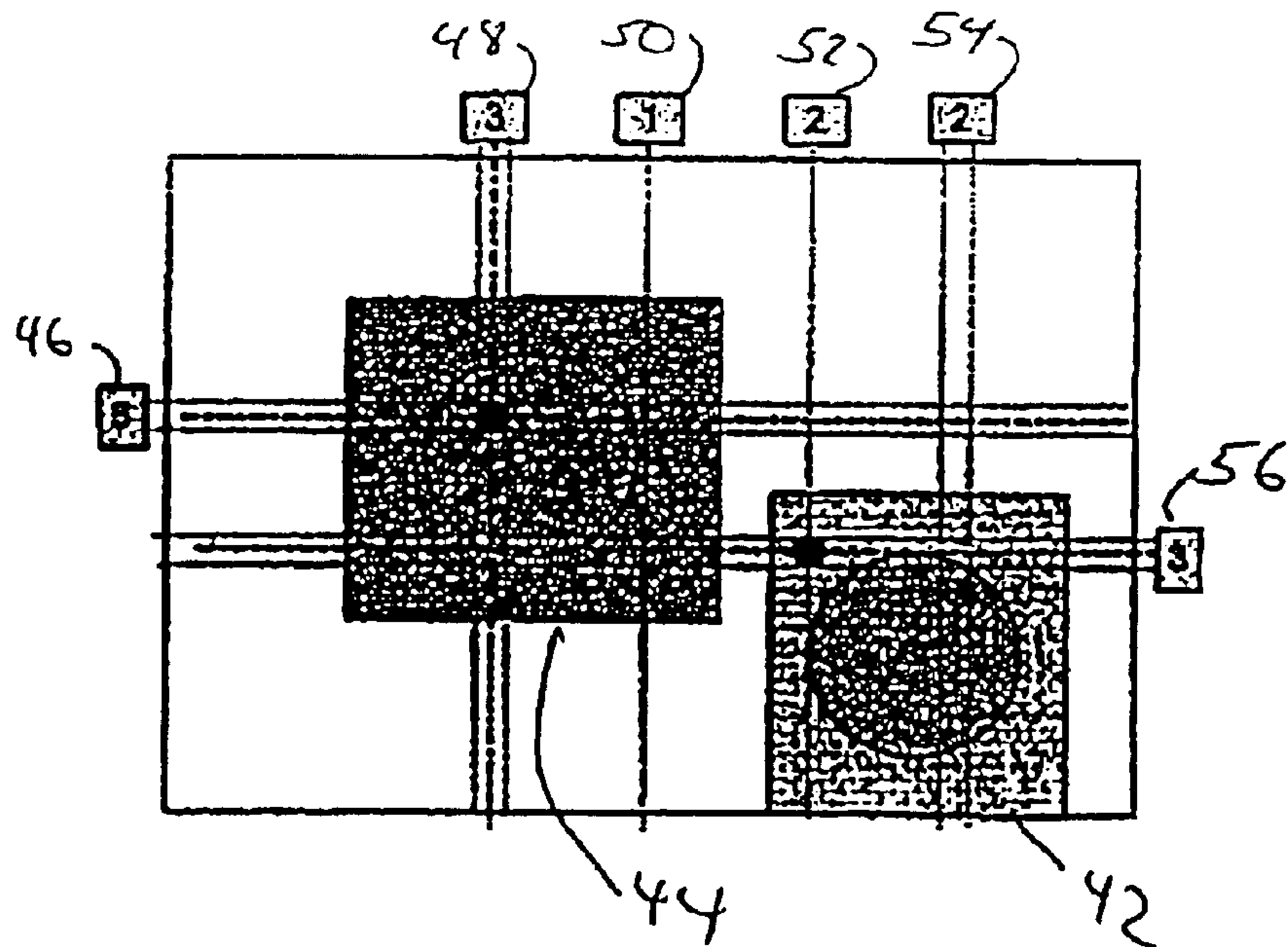



FIG. 14(B)

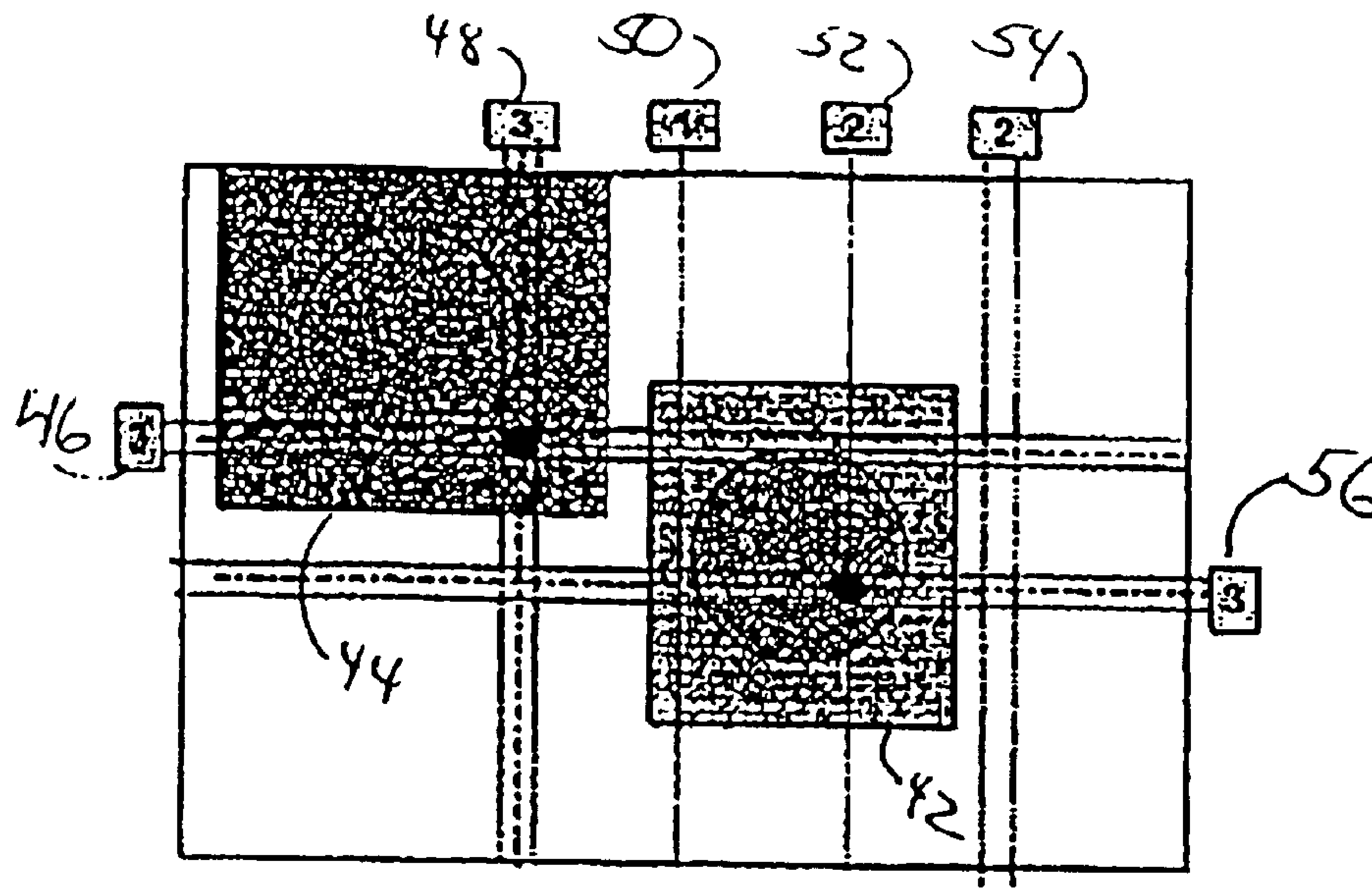



FIG. 14(C)

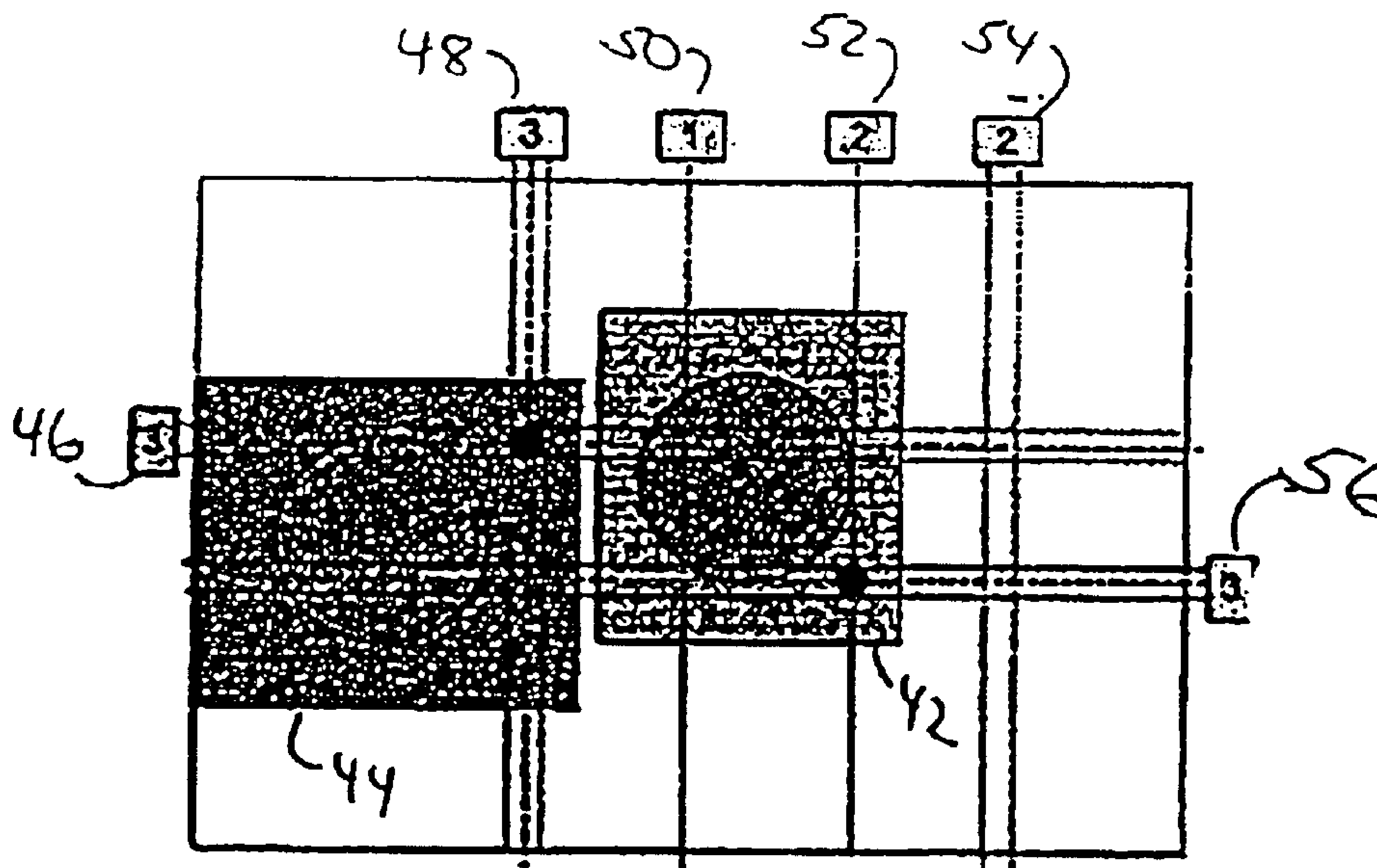



FIG. 14(D)

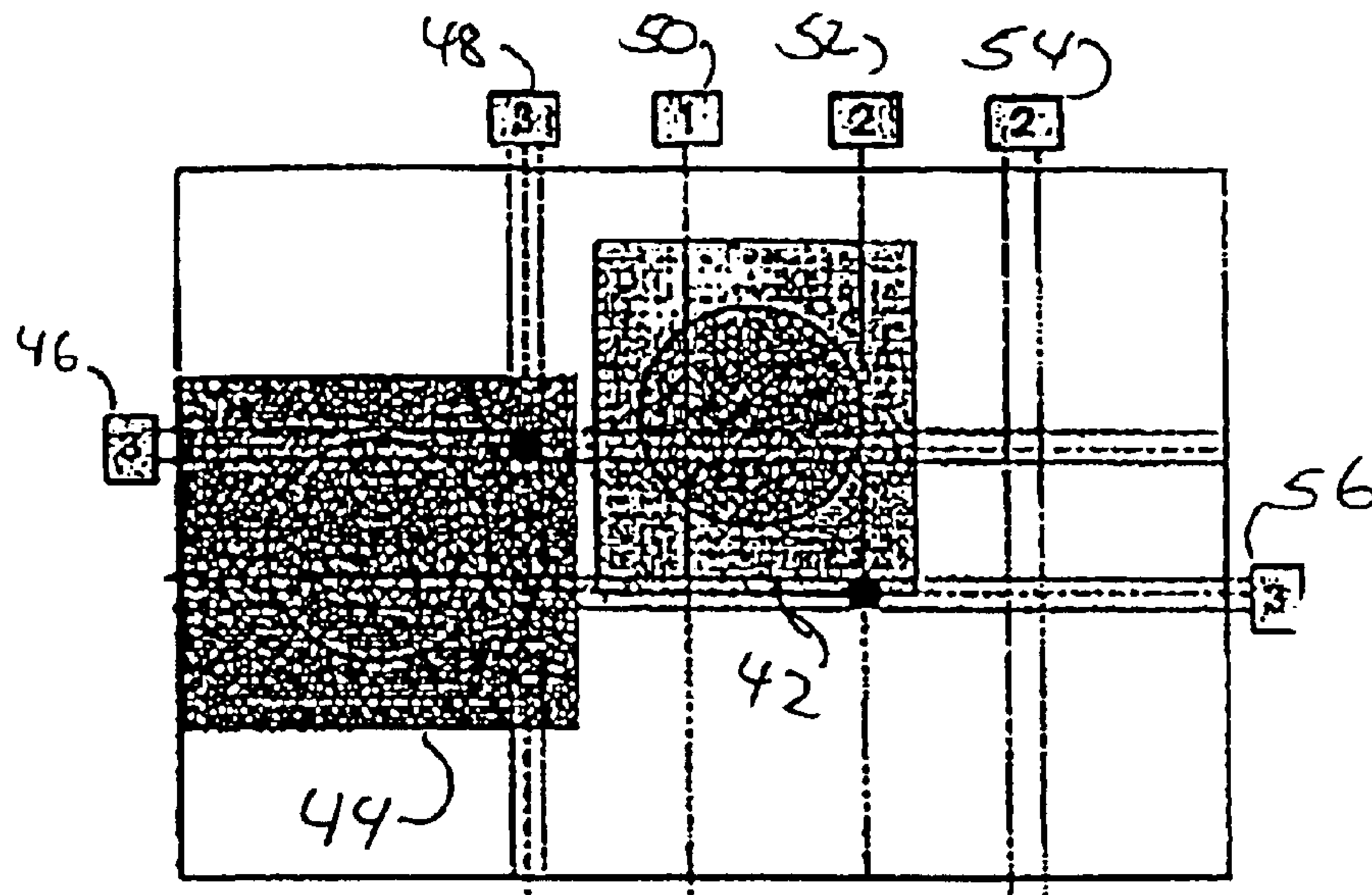



FIG. 14(E)

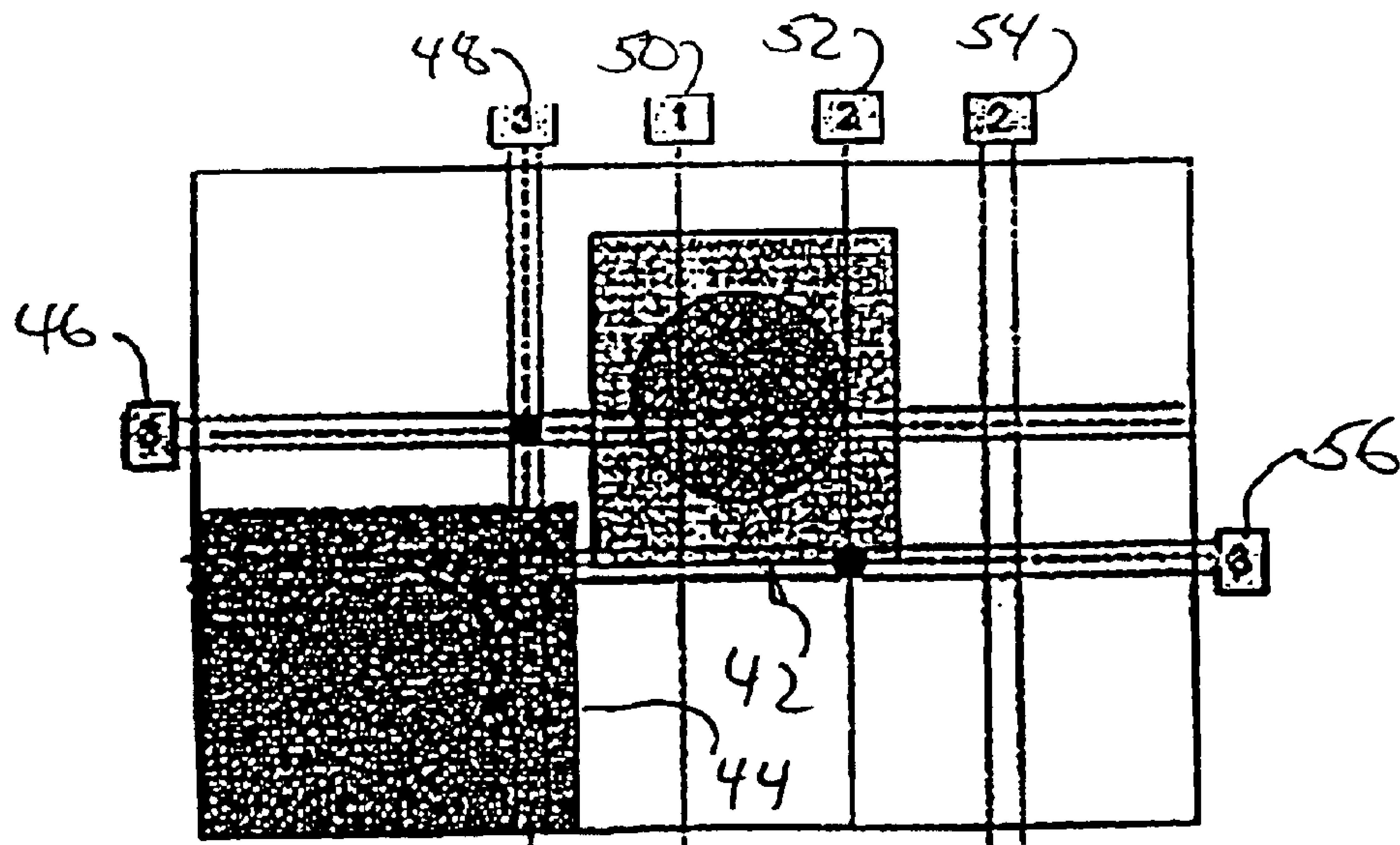



FIG. 14(F)

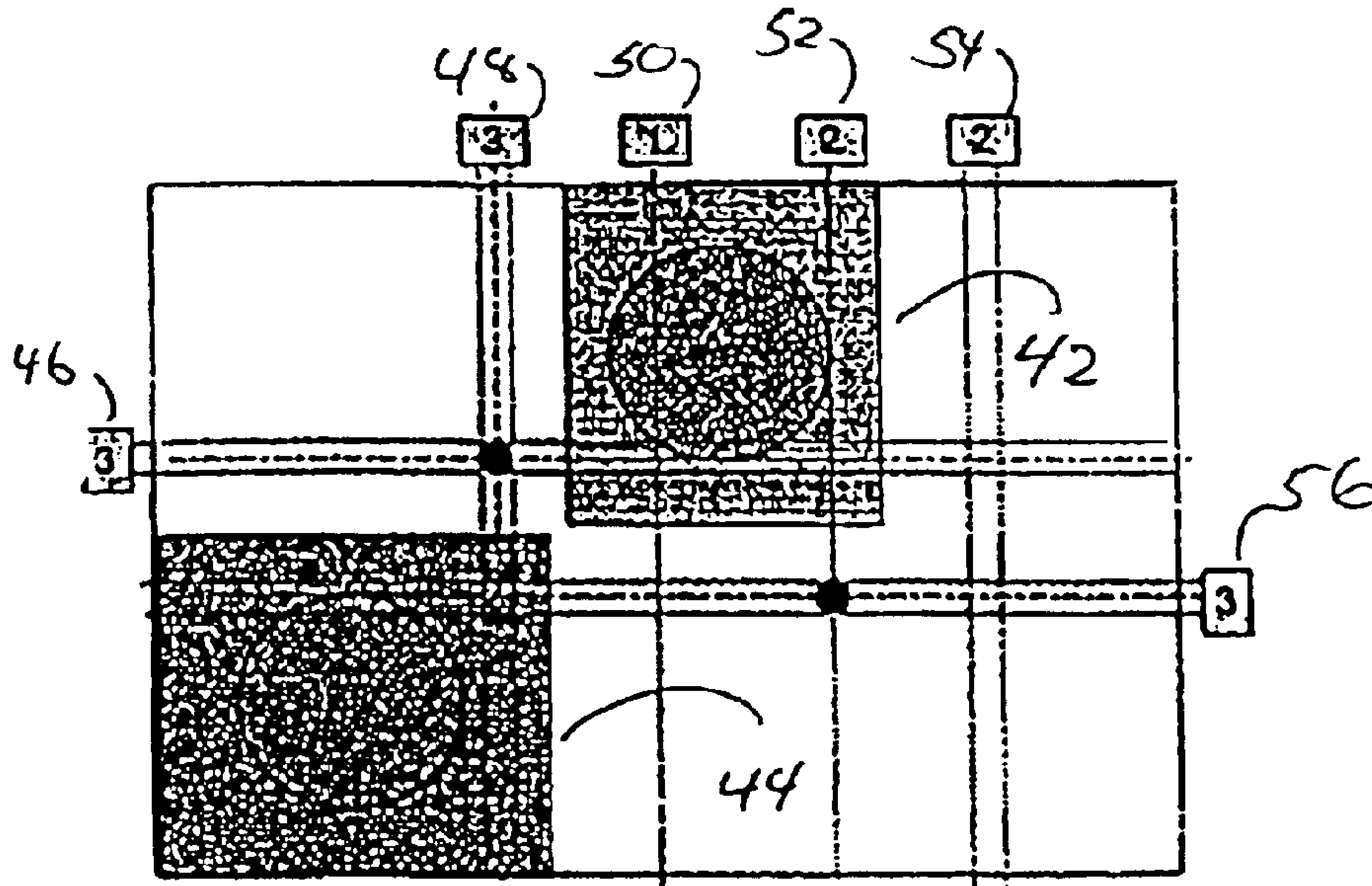



FIG. 14(G)

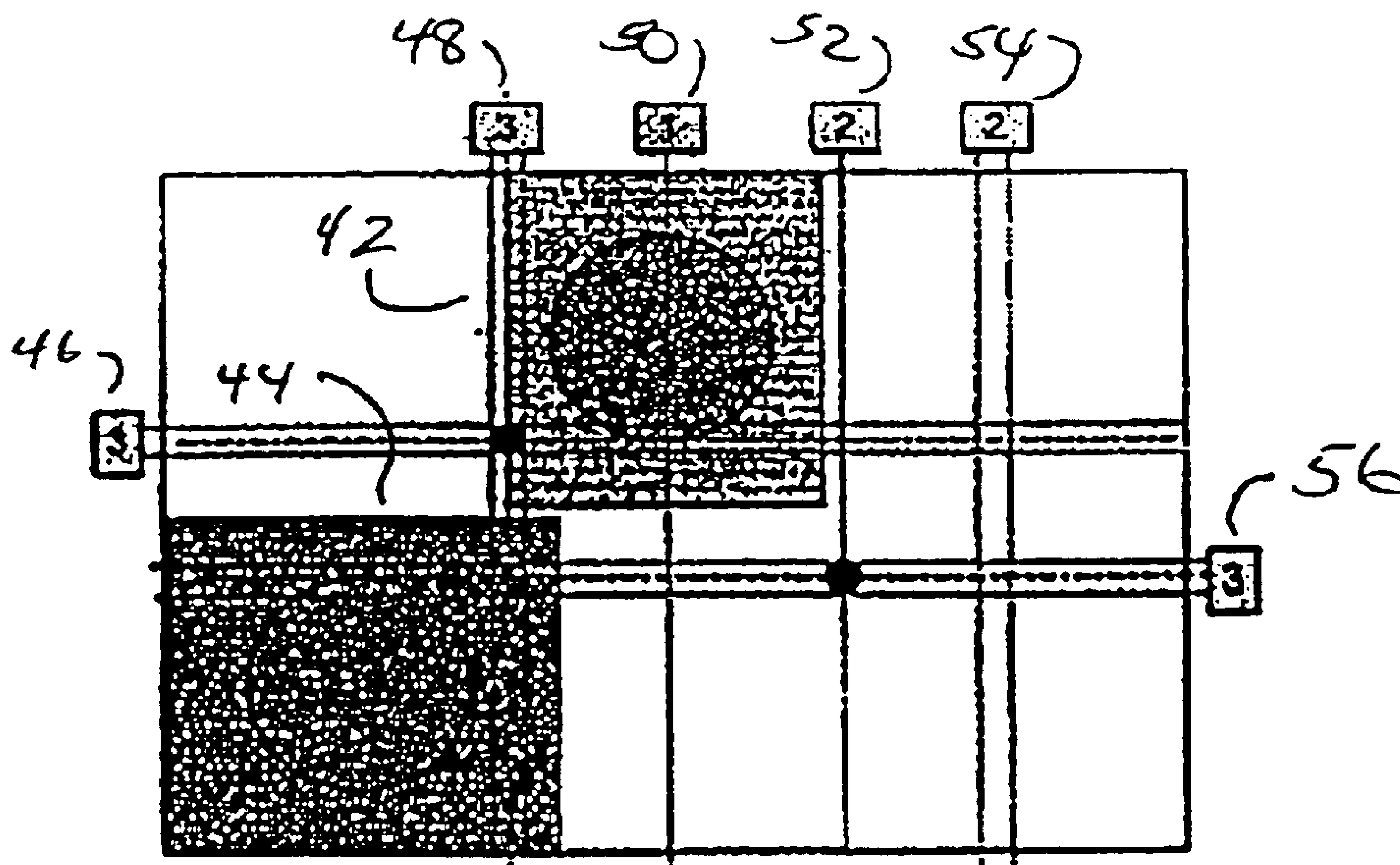



FIG. 14(H)

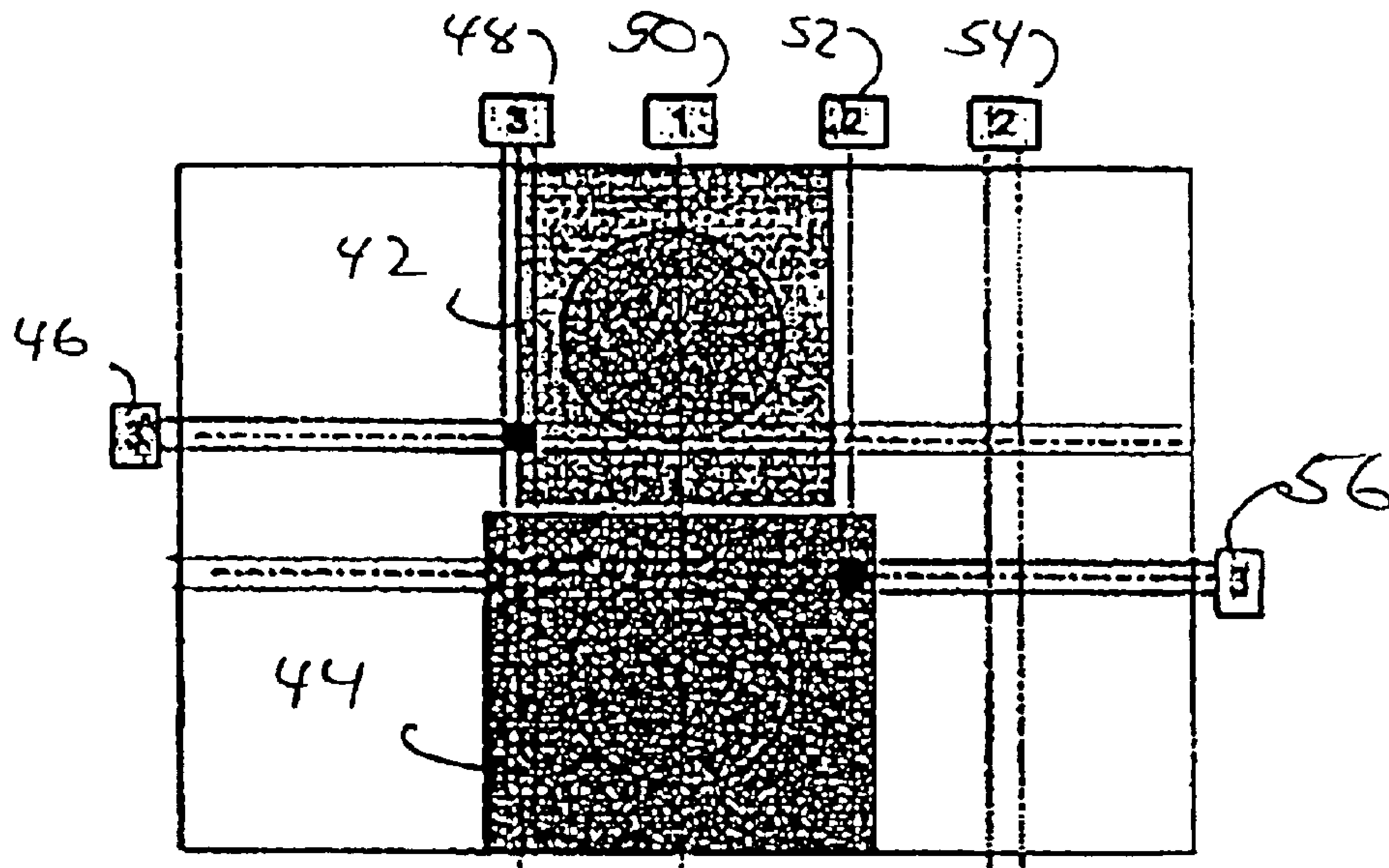



FIG. 14(I)

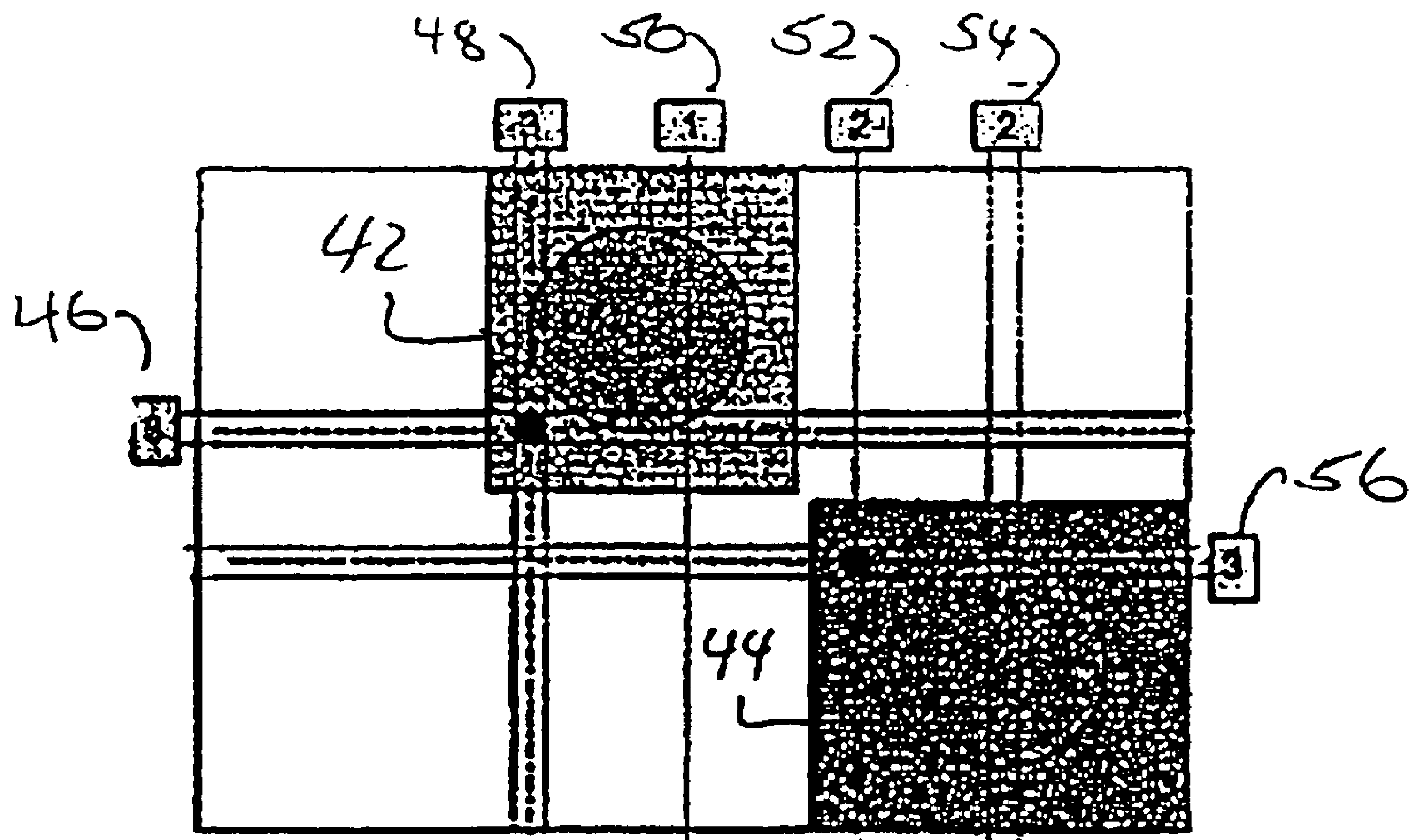



FIG. 14(J)

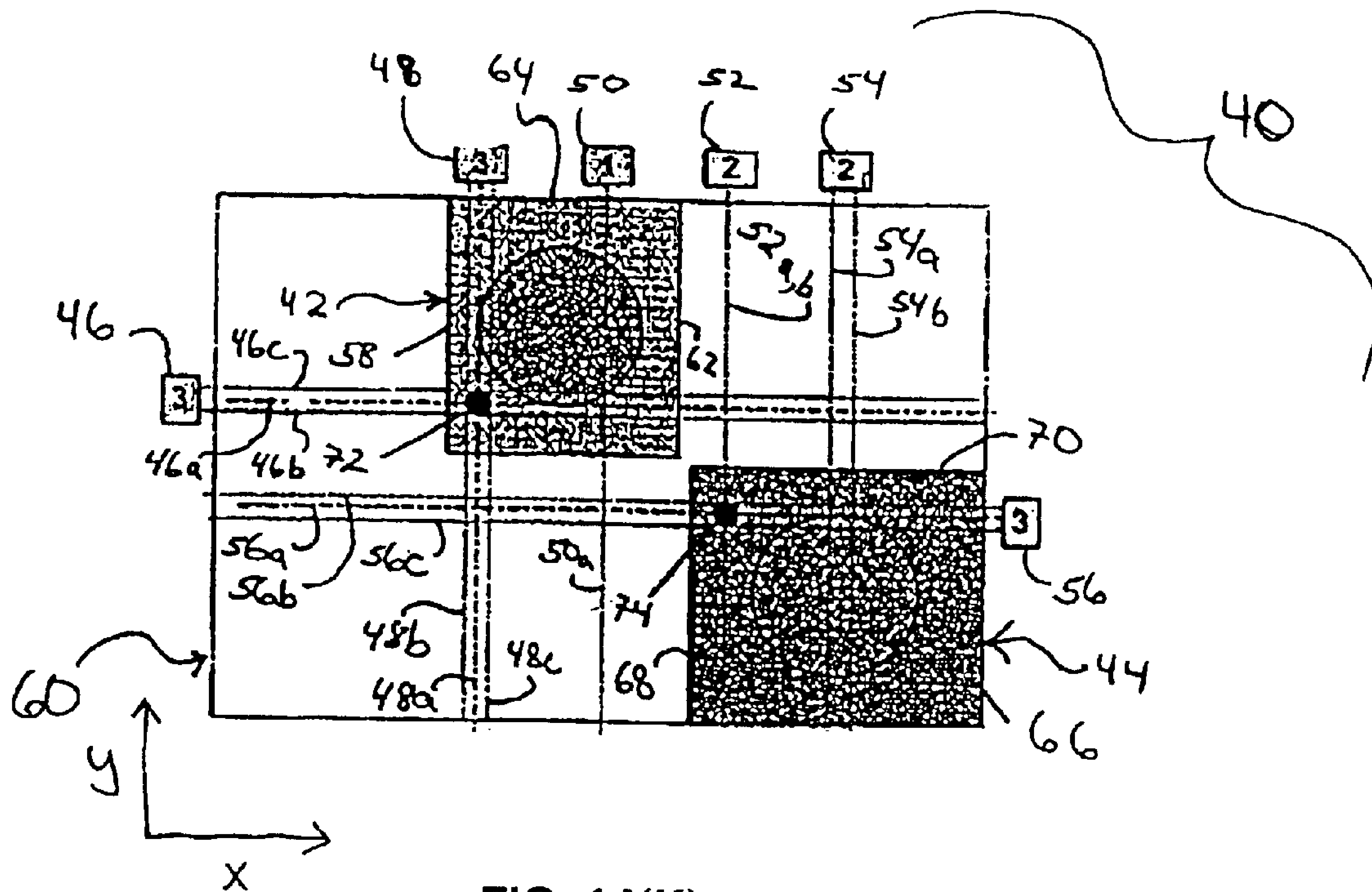



FIG. 14(K)

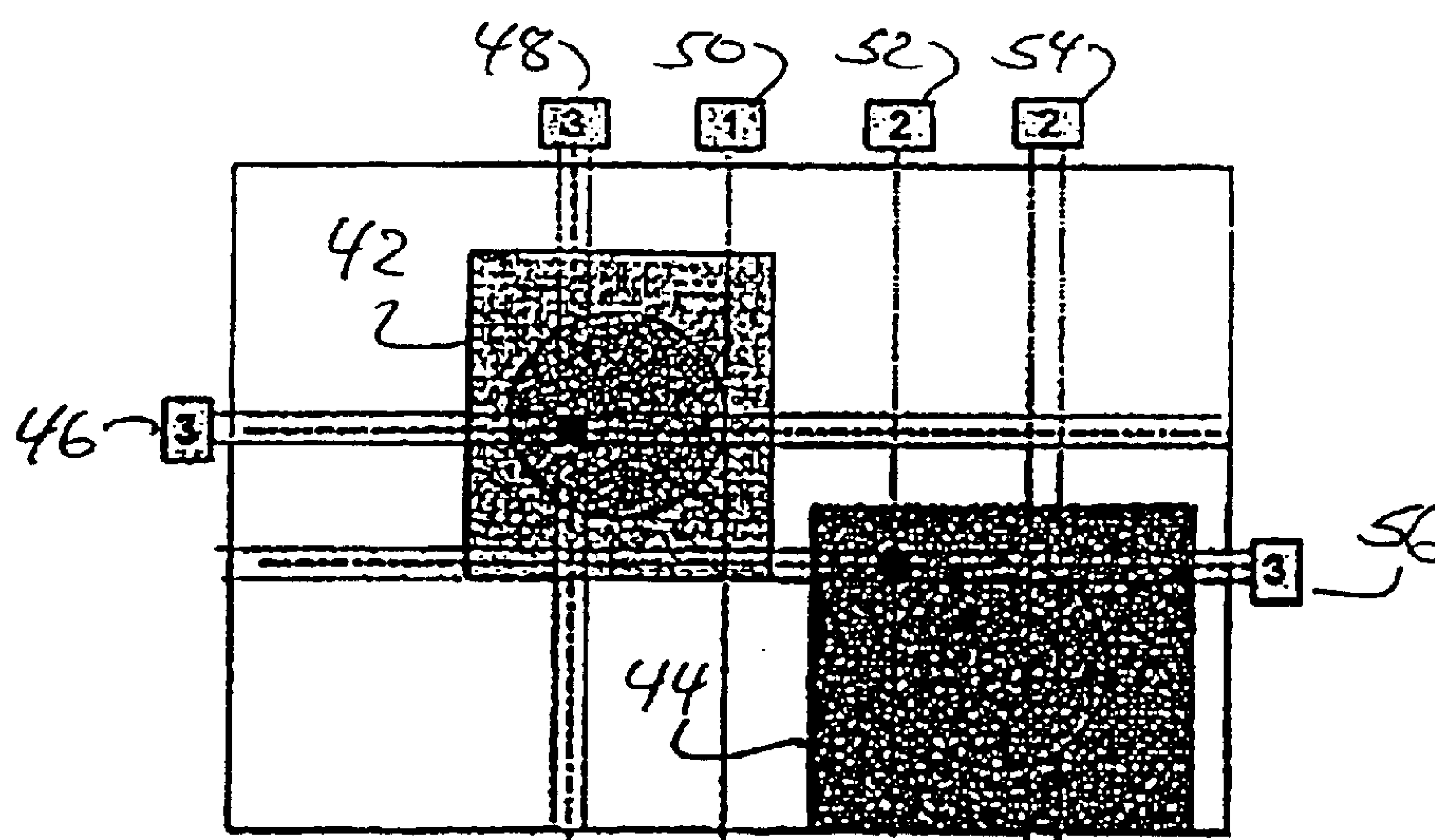



FIG. 14(L)

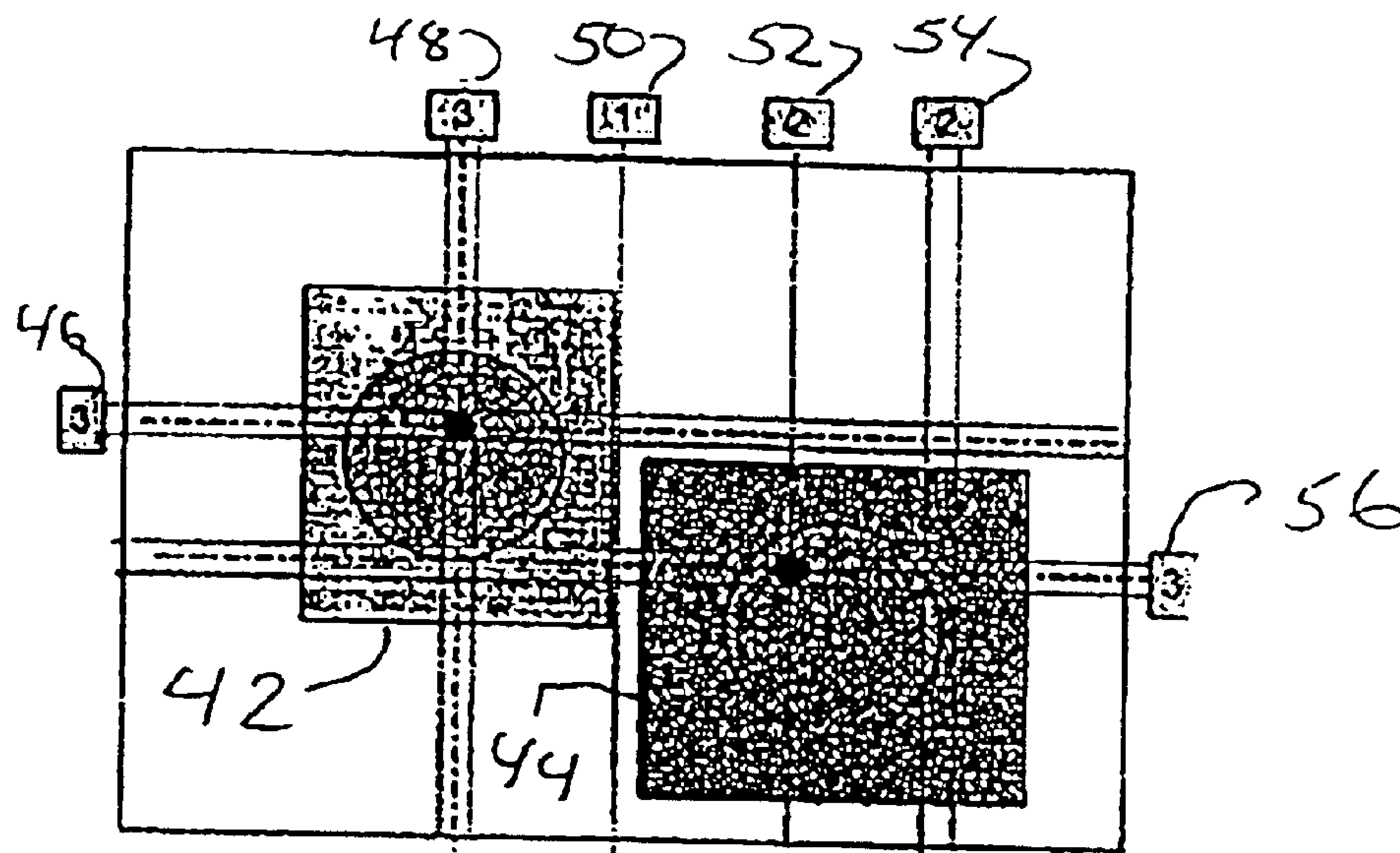



FIG. 14(M)

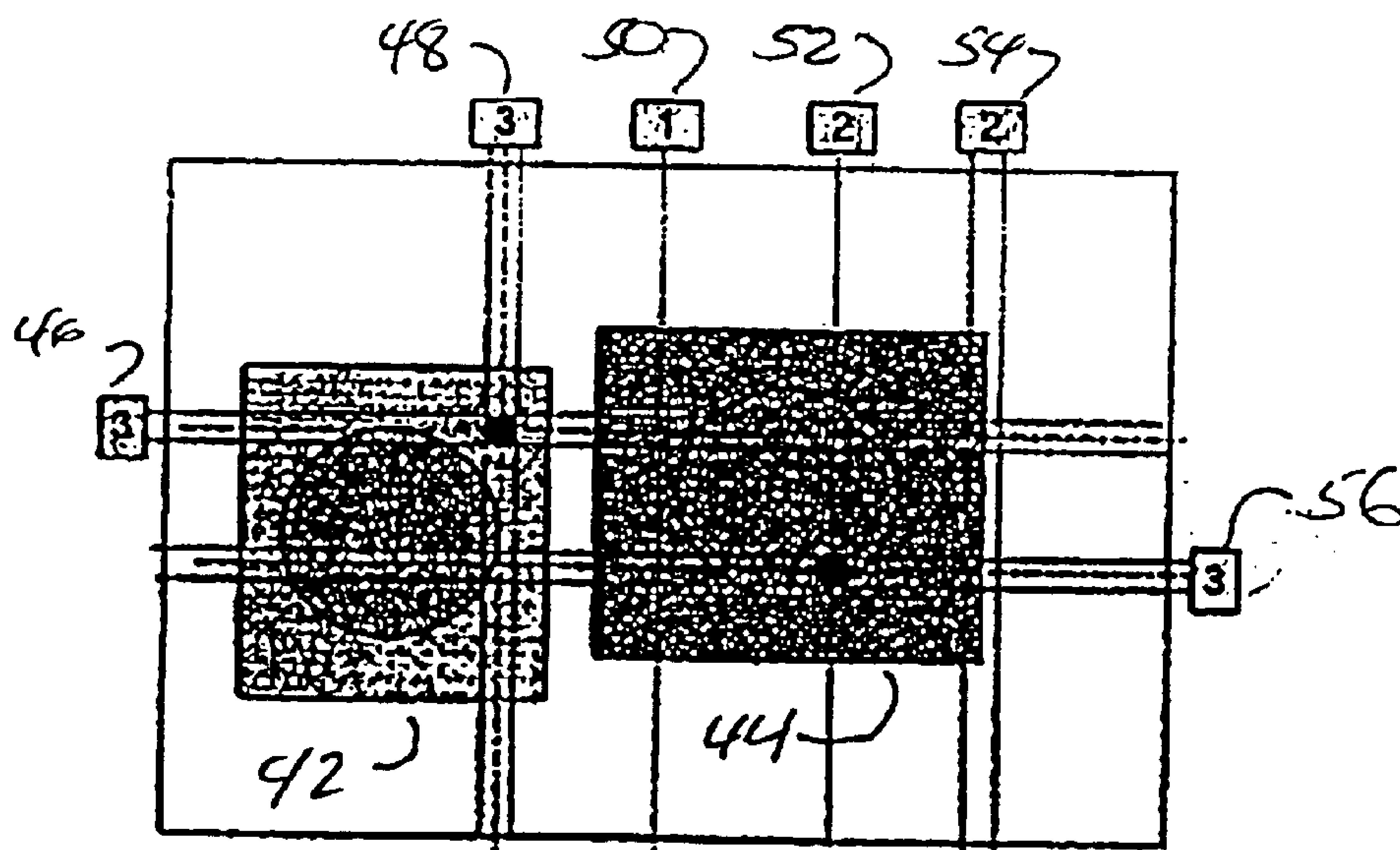



FIG. 14(N)

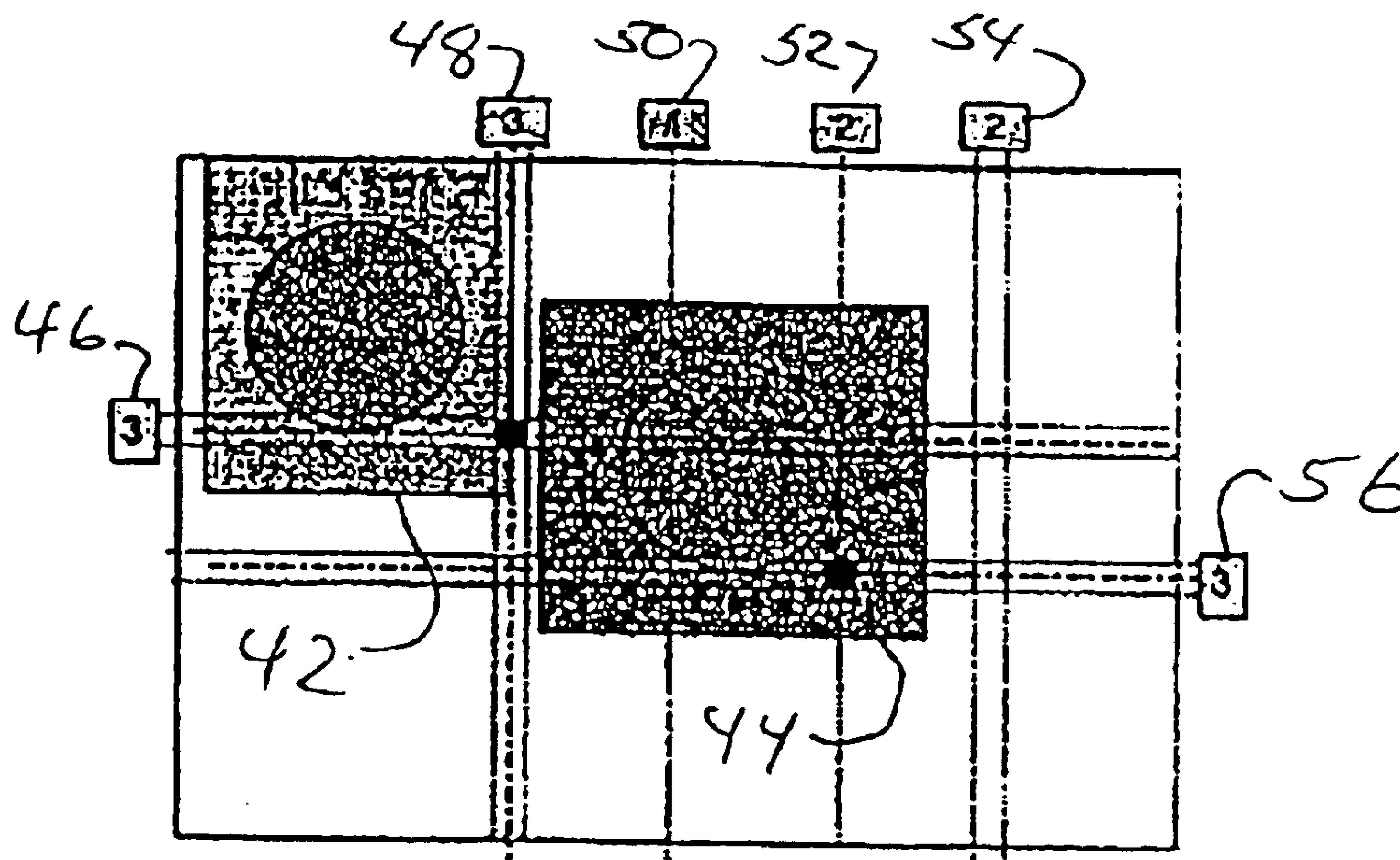



FIG. 14(O)

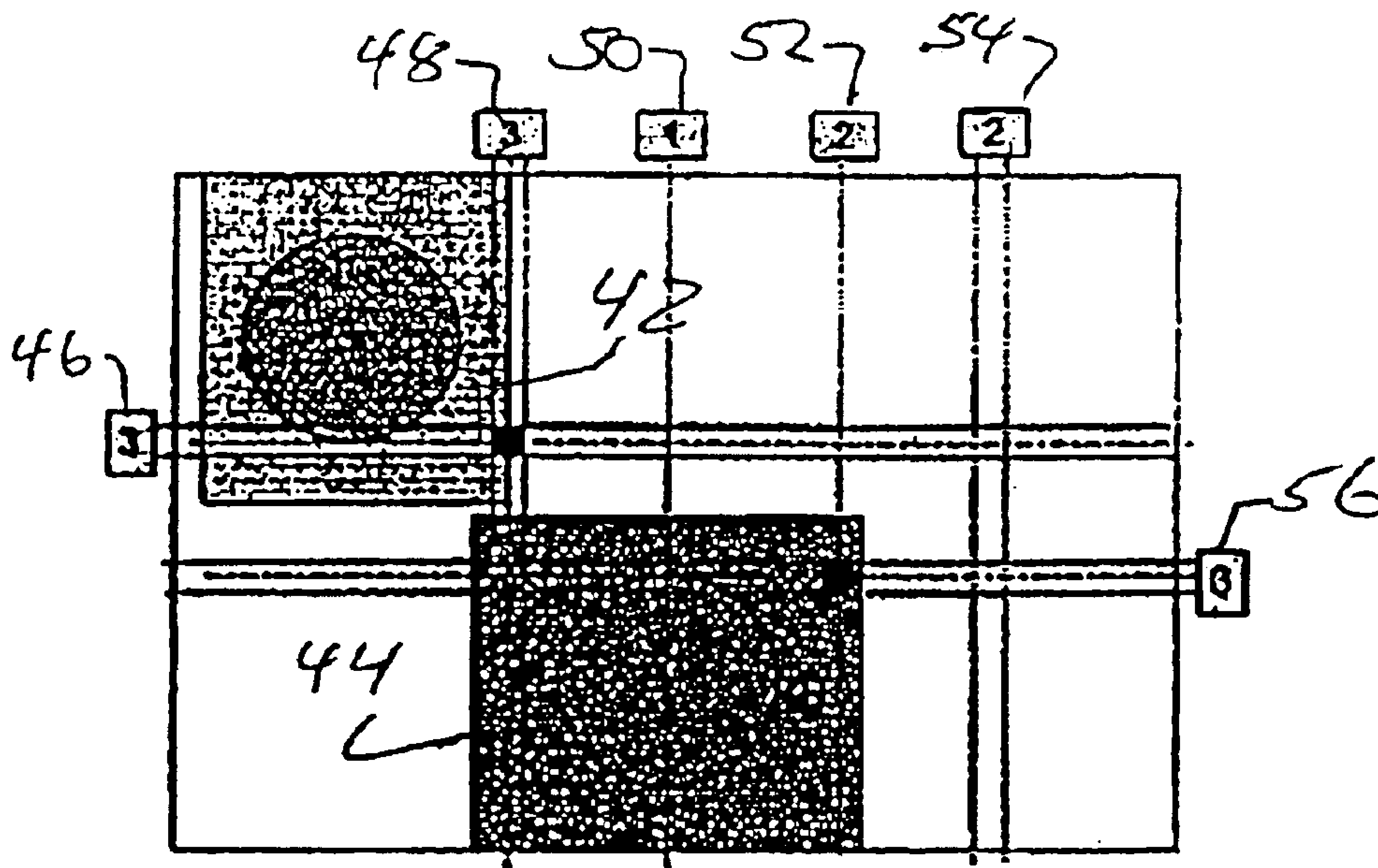



FIG. 14(P)

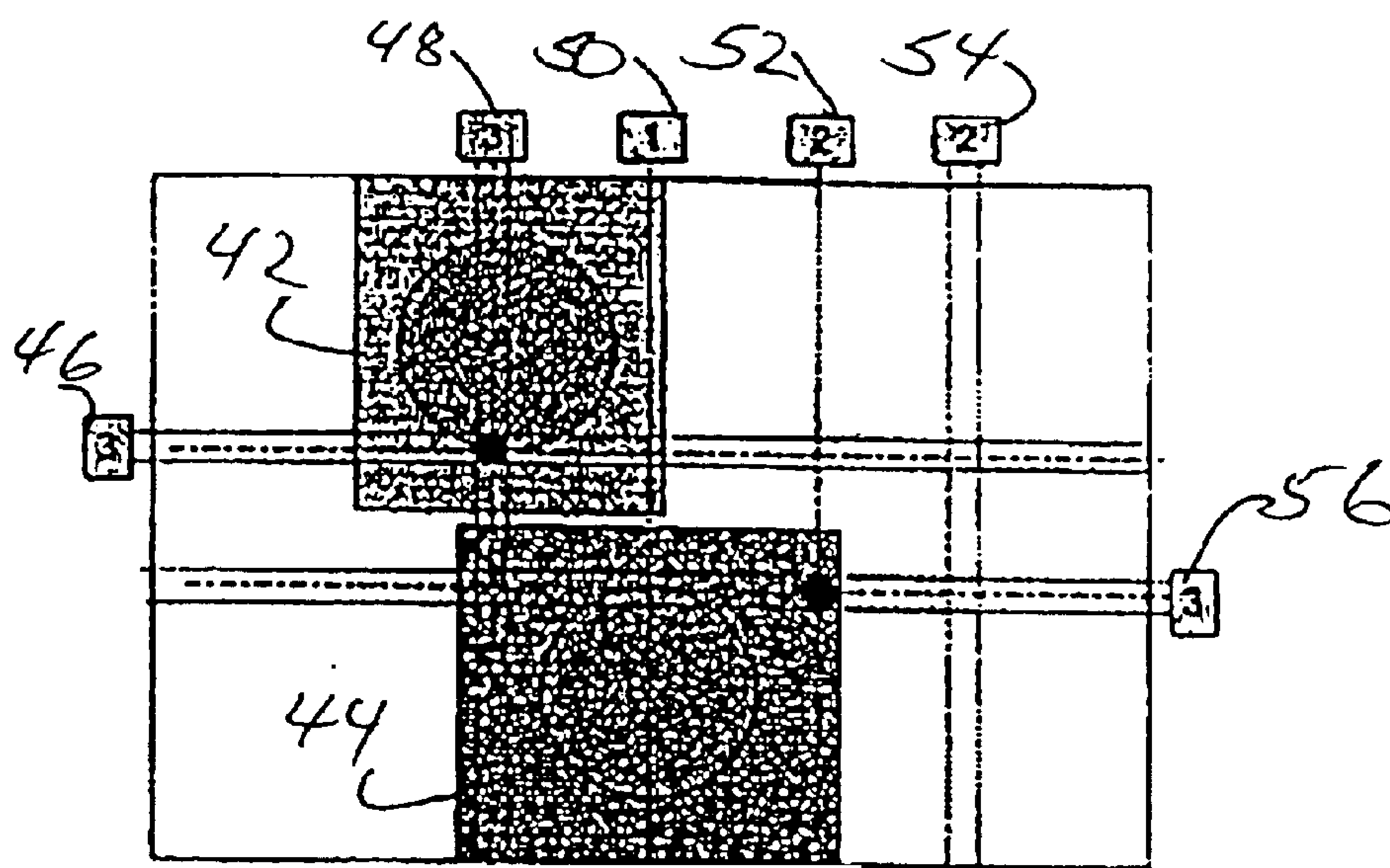



FIG. 14(Q)

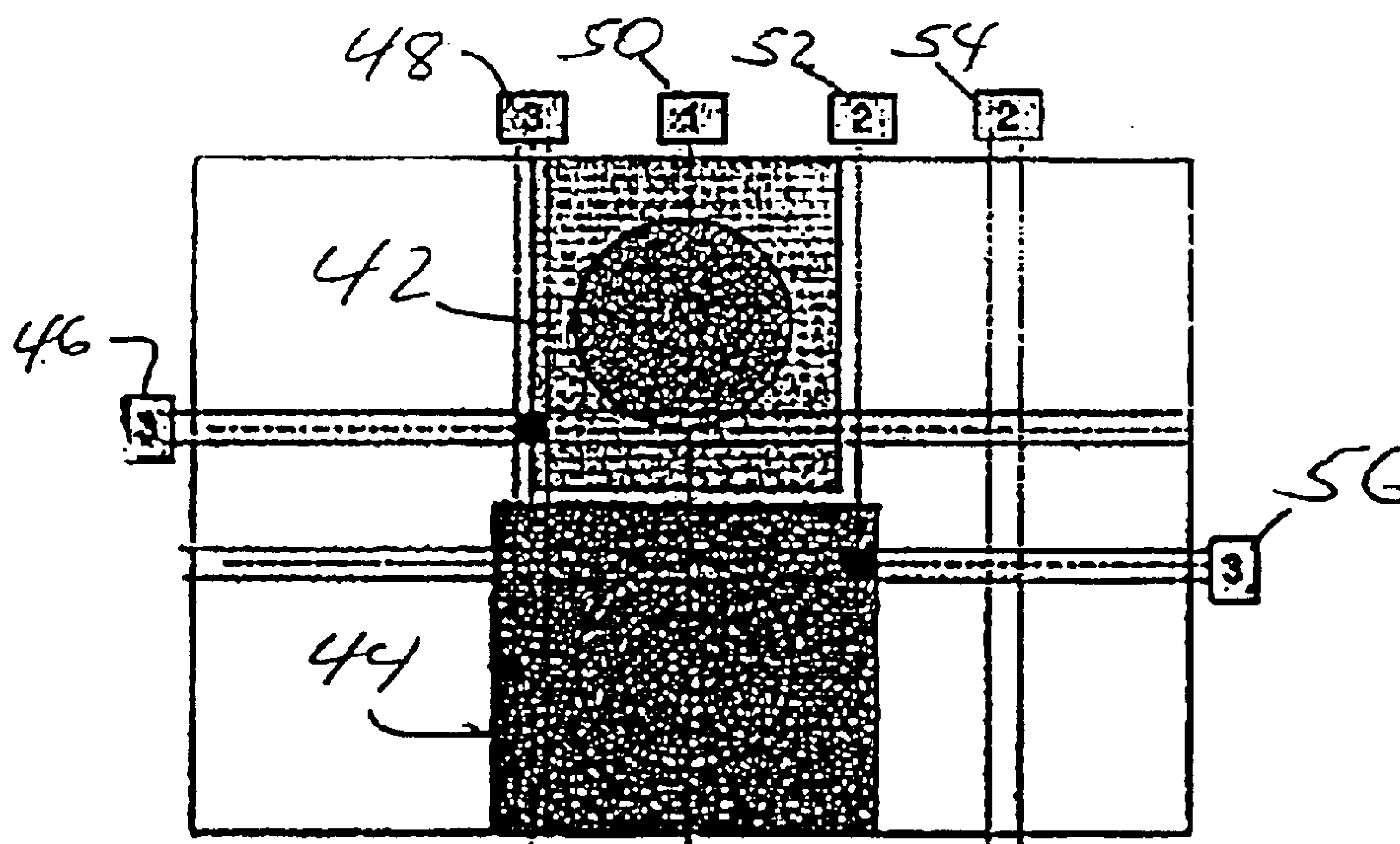



FIG. 14(R)

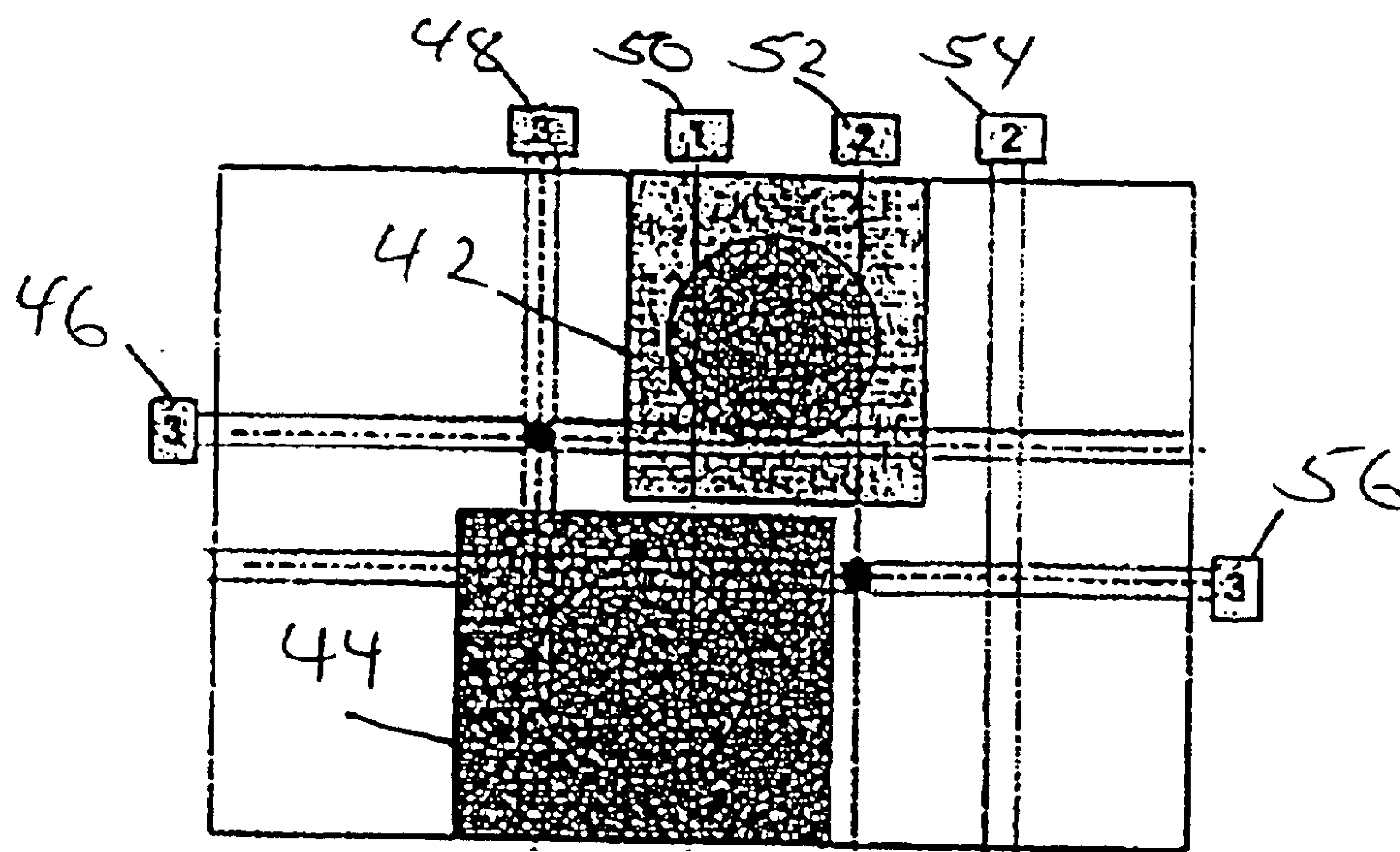



FIG. 14(S)

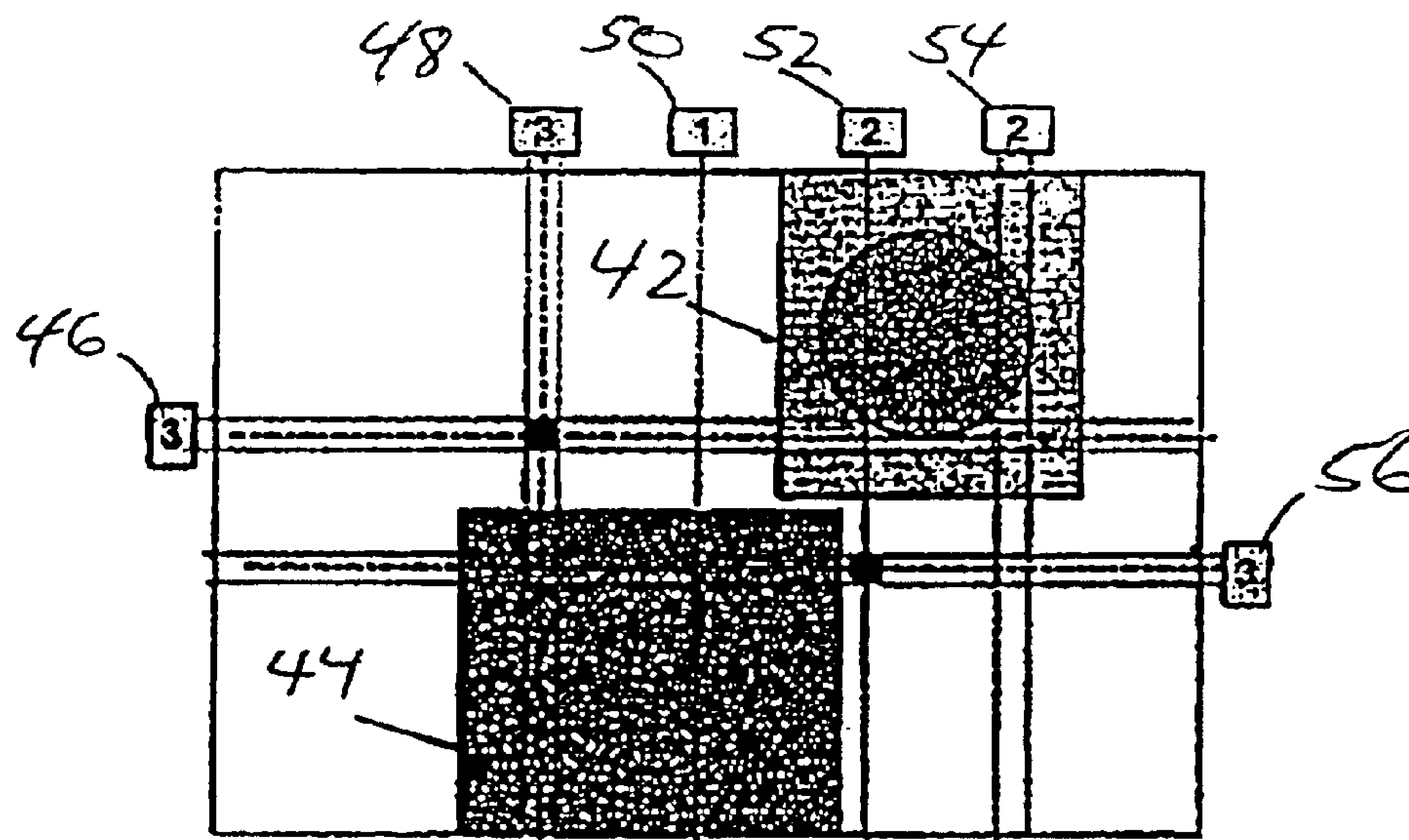



FIG. 14(T)

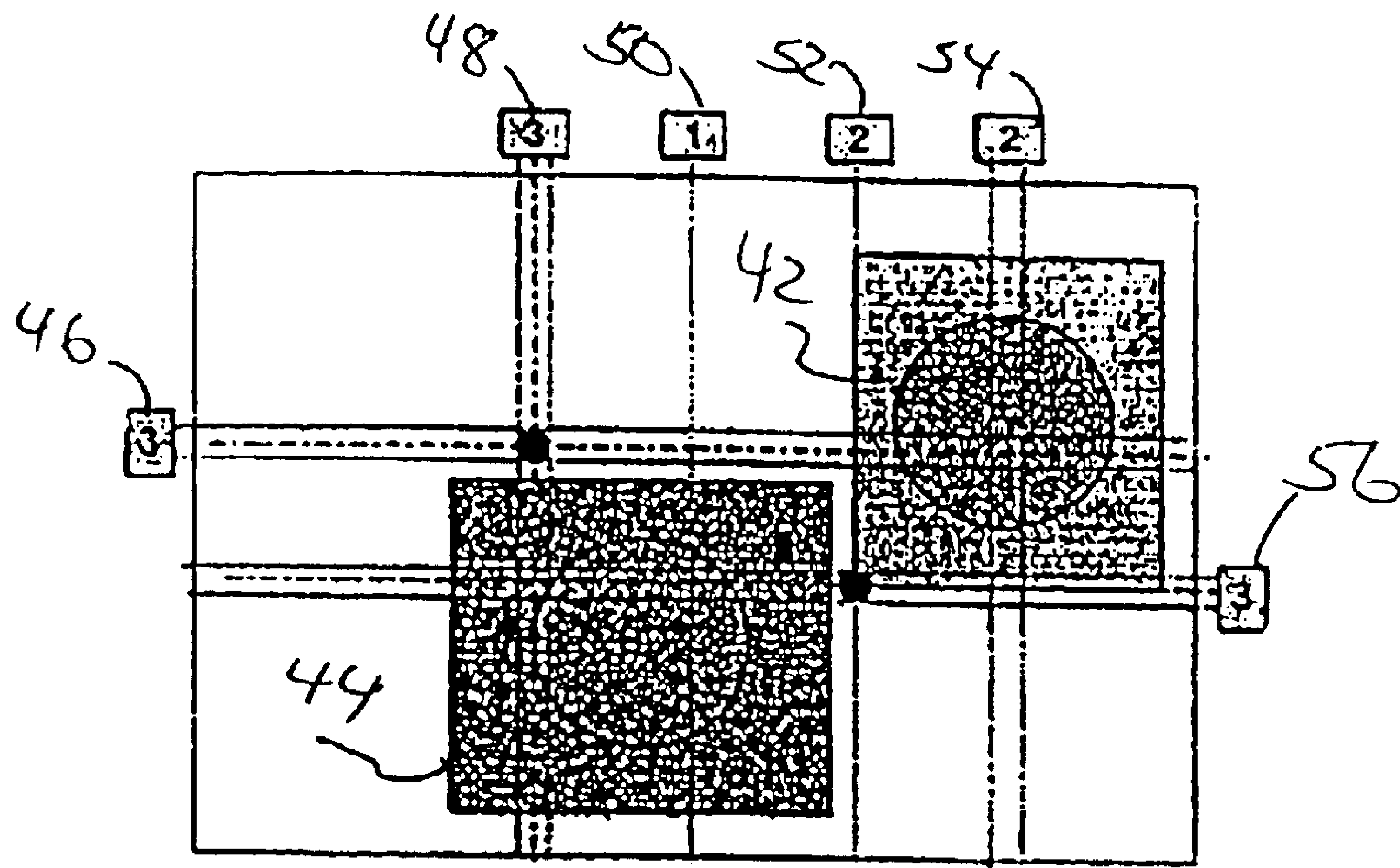



FIG. 14(U)

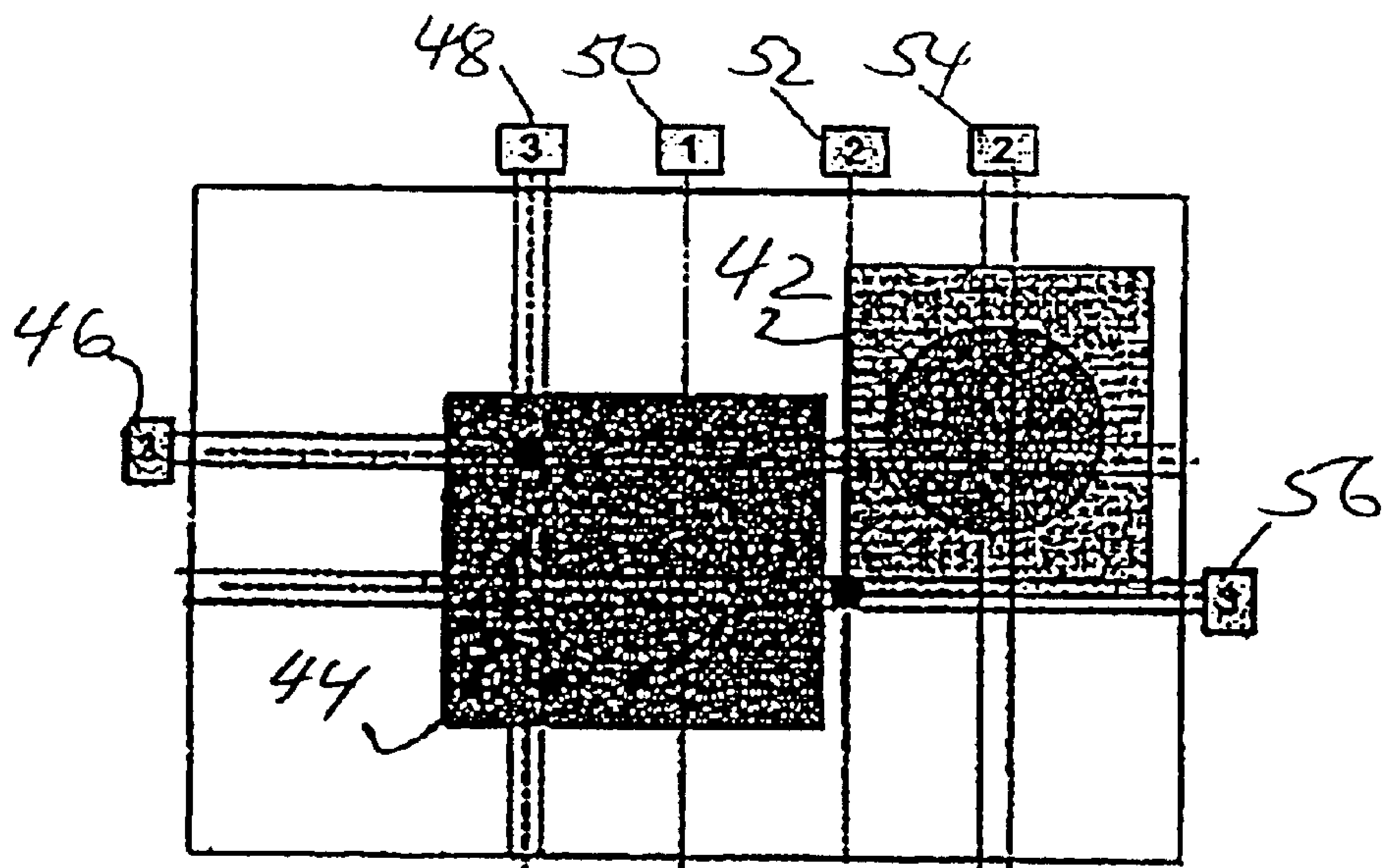



FIG. 14(V)

# SWITCHING TYPE DUAL WAFER STAGE

## FIELD OF THE INVENTION

The invention relates to lithography instruments used for patterning and processing substrates such as semiconductor chips and wafers. More specifically, the invention is concerned with an apparatus and method for using interferometers to determine the position of substrate stages during the simultaneous processing of the substrates affixed to these stages.

## BACKGROUND OF THE INVENTION

Lithography processes require positioning a reticle between an electron beam and the substrate chip or wafer. System throughput is dependent upon the speeds of many separate processes that are performed in series. Throughput is therefore dependent on the duration of each process.

In a typical modern lithography process an individual wafer undergoes a number of sub-processes. These can include: loading, field image alignment, global alignment, and exposure. The production of an acceptable final product requires the complex interaction of the systems necessary to implement each sub-process. For example, in the sub-process for exposing patterns on wafers and other substrates, the reticle is moved at high speeds between discrete and precise positions to facilitate focusing the image on the substrate. This motion can generate dynamic reaction forces where the reticle is supported, leading to distortion of the reticle and, hence, distortion of the image focused on the substrate. Both reticle and wafer must be held without slippage and in a way that does not cause distortion of the reticle pattern. The system is further complicated by the fact that lithography processes typically occur in a clean room/vacuum environment; this is also an indication of the sensitivity of the processes.

A typical exposure apparatus **10** employing a single wafer stage is shown in FIG. **1** and FIG. **2**. Exposure apparatus **10** transfers a pattern of an integrated circuit from reticle **12** onto semiconductor wafer **14**. Apparatus frame **16** preferably is rigid and supports the components of exposure apparatus **10**. These components include: reticle stage **18**, wafer stage **20**, lens assembly **22**, and illumination system **24**. Alternatively, separate, individual structures (not shown) can be used to support wafer stage **20**, reticle stage **18**, illumination system **24**, and lens assembly **22**.

Illumination system **24** includes an illumination source **26** and an illumination optical assembly **28**. Illumination source **26** emits an exposing beam of energy such as light or electron energy. Optical assembly **28** guides the beam from illumination source **26** to lens assembly **22**. The beam illuminates selectively different portions of reticle **12** and exposes wafer **14**. In FIG. **1**, illumination source **26** is illustrated as being supported above reticle stage **18**. Typically, however, illumination source **26** is secured to one of the sides of apparatus frame **16** and the energy beam from illumination source **26** is directed to above reticle stage **18** with illumination optical assembly **28**. Where illumination source **26** is an electron beam, the optical path for the electron beam should be in a vacuum.

Lens assembly **22** projects and/or focuses the light passing through reticle **12** to wafer **14**. Depending upon the design of apparatus **10**, lens assembly **22** can magnify or reduce the image illuminated on reticle **12**.

Reticle stage **18** holds and precisely positions reticle **12** relative to lens assembly **22** and wafer **14**. Similarly, wafer stage **20** holds and positions wafer **14** with respect to the projected image of the illuminated portions of reticle **12**. In the embodiment illustrated in FIG. **1** and FIG. **2**, wafer stage **20** and reticle stage **18** are positioned by shaft-type linear motors **30**. Depending upon the design, apparatus **10** may include additional servo drive units, linear motors and planar motors to move wafer stage **20** and reticle stage **18**, but other drive and control mechanisms may be employed.



The basic device as described may be used in different types of lithography processes. For example, exposure apparatus **10** can be used in a scanning type lithography system, which exposes the pattern from reticle **12** onto wafer **14** with reticle **12** and wafer **14** moving synchronously. In a scanning type lithography process, reticle **12** is moved perpendicular to an optical axis of lens assembly **22** by reticle stage **18**, and wafer **14** is moved perpendicular to an optical axis of lens assembly **22** by wafer stage **20**. Scanning of reticle **12** and wafer **14** occurs while reticle **12** and wafer **14** are moving synchronously.

Alternatively, exposure apparatus **10** may be employed in a step-and-repeat type lithography system that exposes reticle **12** while reticle **12** and wafer **14** are stationary. In the step-and-repeat process, wafer **14** is in a constant position relative to reticle **12** and lens assembly **22** during the exposure of an individual field. Subsequently, between consecutive exposure steps, wafer **14** is consecutively moved by wafer stage **20** perpendicular to the optical axis of lens assembly **22** so that the next field of semiconductor wafer **14** is brought into position relative to lens assembly **22** and reticle **12** for exposure. Following this process, the images on reticle **12** are sequentially exposed onto the fields of wafer **14**.

This complexity and sensitivity of the exposure apparatus and the processes involved result in a significant time expenditure for each sub-process. When a single wafer is undergoing one of these sub-processes, the mechanisms for the others are normally idle. Consumer demand for the end product has created a need for increased throughput and, thus, the development of methods to decrease the idle time. One current method uses two stages that run simultaneously, but with each stage at different steps in the process. This method relies upon a combination of encoders and interferometers to determine the position of each stage at any given point throughout processing.

Encoders, however, are less than ideal devices for this use for a number of reasons. The encoder must be placed in an area that does not interfere with the requirements of other sub-processes, such as substrate exposure. This leads to apparatus design problems in harmonizing the requirements of the encoder, interferometers, and the process. Also, encoders are less precise than interferometers. Precision in planar placement of the stage is necessary, since errors in reticle or wafer position result in similar errors in the final product and, therefore, reduced functionality of that final product.

## SUMMARY OF THE INVENTION

The present invention provides a dual stage assembly and method where stage position may be determined using interferometers. The stage assembly includes a plurality of interferometers mounted on a base for determining stage positions. The two stages move between multiple positions on the base and have mirrors affixed to them that cooperate with the other interferometer components to provide position data. At times, the two stages are positioned so that the first stage eclipses the second stage with respect to said at

least one of the interferometers. Whenever such an eclipse occurs, the mirror on the second (eclipsed) stage is configured to cooperate with the non-eclipsed interferometers so that the position of said second stage is continuously determinable. This is achieved by appropriately dispersing the interferometers about one side of the base and by causing the mirror on the second stage to extend from behind the eclipsing shadow of the first stage. In a preferred embodiment, the second stage is the same size as the first and merely supports the larger mirror. In another preferred embodiment, the second stage is approximately the same size as the mirror in the relevant dimensions. In both the previously mentioned preferred embodiments the stages are the same size in the direction parallel to the axes of the interferometers. But the invention could also be practiced in two dimensions resulting in the need for interferometers on only two orthogonal sides of the base.

A method incorporating the invention comprises: sizing the stages based on wafer and exposure apparatus parameters; dispersing interferometers about the sides of the base at appropriate positions based on the stage sizes; configuring the mirror on the second stage to continue to cooperate with enough other interferometer elements to provide position data even if the first stage is positioned between the second stage and some of the interferometers; moving the stages as desired during the course of using the exposure apparatus; and determining the positions of both stages at all times during the process. A preferred embodiment of the invention practices the method with respect to one dimension of the apparatus; resulting in interferometers on three sides of the base. Another embodiment of the invention practices the method with respect to both dimensions of the plane of movement; resulting in interferometers on two orthogonal sides of the base.

## BRIEF DESCRIPTION OF THE DRAWINGS

The foregoing and other aspects and advantages will be better understood from the following detailed description of the preferred embodiment of the invention with reference to the drawings, in which:

FIG. **1** is a side view of a lithography exposure apparatus of the prior art;

FIG. **2** is a different side view of a lithography exposure apparatus of the prior art;

FIG. **3** is a top view of a dual wafer stage assembly incorporating a preferred embodiment of the present invention;

FIG. **3***a* is a schematic plan view of an alternative embodiment of a stage according to the invention;

FIG. **4***a* is a top view of a first wafer stage;

FIG. **4***b* is an enlarged detail view of portion B of the first wafer stage shown in FIG. **4***a*.

FIG. **5** is a top plan view of a first wafer stage eclipsing a second wafer stage in a preferred embodiment of the present invention;

FIG. **6** is a top view of a second wafer stage in a preferred embodiment of the present invention;

FIG. **7** is a top view of first and second wafer stages showing the Y swept area of dual wafer stage assembly **40** in example 1;

FIG. **8** illustrates a first position involved in determining the X swept area of dual wafer stage assembly **40** in example 1;

FIG. **9** illustrates a second position involved in determining the X swept area of dual wafer stage assembly **40** in example 1;

FIG. **10** illustrates the mechanical margin as described in example 1;

FIG. **11** illustrates an arrangement of wafer stage cover as described in example 1;

FIGS. **12**(*a*)–(*d*) illustrate interferometer axes configuration in example 1;

FIG. **13**(*a*)–(*e*) is a flowchart illustrating a method according to the present invention; and

FIGS. **14**(*a*)–(*v*) illustrate steps **1**–**22** of the method shown in FIGS. **13**(*a*)–(*c*).

## DETAILED DESCRIPTION OF THE INVENTION

Referring now to FIG. **3**, dual wafer stage assembly **40** is illustrated from above according to a preferred embodiment of the invention. This invention minimizes the number of interferometers necessary for positioning by configuring the stages according to the invention so that one stage never totally eclipses the other. Dual wafer stage assembly **40** provides the capability for the system to rely on interferometers **46, 48, 50, 52, 54, 56** to determine the position of wafer stages **42, 44** during processing. Dual wafer stage assembly **40** generally comprises a first wafer stage **42**, a second wafer stage **44**, a base **60**, and the interferometers mentioned above. Each interferometer cooperates with a reflective surface (mirror) **58, 62, 64, 66, 68, 70** mounted on stages **42, 44** so that they reflect back to the intended interferometer.

As shown in FIG. **3**, focal point **72** refers to the point where the image from reticle **12** is focused by the projection apparatus onto stage **40**. Area **74** identifies an area that an operator views from above (typically with a microscope) to determine if the wafer is properly aligned. This area is referred to as the field image alignment area or point. Interferometer **50** is positioned approximately midway between projection lens **72** and field image alignment point **74** in the X-direction and is used for control when stages **42, 44** are moving in the Y-direction. Interferometer **54** is positioned to determine stage location during loading (stage safety position) as illustrated.

Mirrors **58, 62, 64, 66, 68, 70** are known as "moving mirrors" because they move with wafer stages **64, 66**. As is understood by persons skilled in the art, other non-moving mirrors known as "reference mirrors" are located within the interferometers **46, 48, 56, 52, 50** and **54**, but in order to clarify the schematic representation of the invention standard reference beams, reference mirrors, and sensors for each interferometer are not shown.

Elements of base **60** necessary for the support, positioning, and movement of wafer stages **42, 44** are also not illustrated in FIG. **3** for purposes of clarity, but as one of skill in the art would recognize, these functions may be accomplished by the shaft-type linear motors **30** or other known actuators and additional static support elements of the prior art (see FIGS. **1** & **2**). Also, the individual axes (beams) of interferometers **46, 48, 56, 52, 50** and **54** are configured and utilized either singularly or in combination to make possible the measurements necessary at any particular moment. For example, although the single beam of interferometer **50** is primarily used to determine Y position of wafer stage A when switching in the Y direction, it is also used at times in conjunction with interferometer **52** to determine the stage A yaw. In a preferred embodiment, the present invention employs one, two, and three axes interferometers that are incident on dual wafer stages **42, 44** from three sides to determine wafer stage position at all times. As

shown in FIGS. 12(*a*)–(*d*), the axes of the interferometers are directed in parallel towards the moveable mirrors on stages **42**, **44**, but are arranged to provide position data from different points on the moveable mirrors. Position data from one axis may therefore be combined with position data from one or more other axes and manipulated to yield stage yaw and pitch. As is well known to one of skill in the art, the spacing between axes necessary for them to combine to yield yaw and pitch data is infinitely variable in three dimensions so long as the beam is incident upon the desired mirror.

Continuing with FIG. **3**, and viewing the interferometers in more detail in FIG. **12**, interferometers **46**, **48**, **56** each have 3 axes **46***a*, **46***b*, **46***c*, **48***a*, **48***b*, **48***c*, **56***a*, **56***b*, **56***c* and is capable of determining X position, yaw, and pitch. Interferometers **52**, **54** each have 2 axes **52***a*, **52***b*, **54***a*, **54***b* and is capable of determining Y position and pitch. Interferometer **50** has one axis **50***a* and is capable of determining Y position, but if roll and pitch control are also required in addition to the X position, Y position, and yaw control, then interferometer **50** preferably has 2 axes and is capable of determining Y position and pitch, similar to interferometer **52**. If roll and pitch control are also required in addition to the X position, Y position, and yaw control, then interferometer **54** preferably has 3 axes and is capable of determining Y position, yaw, and pitch. In this preferred embodiment the minimum number of axes necessary to implement the invention is 14, as shown in FIG. **14**.

In a preferred embodiment shown in FIG. **3** interferometers **46**, **48**, **52**, and **56** are directed so their axes determine the positions of wafer stages **42**, **44** closest to the most significant areas. Interferometers **46**, **48** intersect at focal point **72** where the projection lens focuses the image from the reticle. Interferometers **56** and **52** similarly intersect at field image alignment point **74**. In order to prevent all of interferometers **48**, **50**, **52**, **54** from being eclipsed by first stage **42** whenever it is positioned between second wafer stage **44** and said interferometers, second stage **44** is preferably larger in the X-direction than first stage **42**. Thus, moving mirrors positioned on second stage **44** that cooperate with interferometers **48**, **50**, **52**, **54** are at least in part disposed at peripheral edge portions of the second stage so as to be accessible to the interferometers around the first stage. In a preferred embodiment, these moving mirrors comprise a single, continuous mirror that extends along the entire side of the stage to permit interferometer readings at any point. Alternatively, rather than increasing the size of the stage as a whole, it will be appreciated that extension structures **43** may be provided on second stage **44**' to carry the moving mirror(s) as schematically illustrated in FIG. **3***a*.

By properly placing the interferometers and configuring the stages or the moveable mirrors mounted on the stages, this invention provides a dual wafer stage assembly that positions the stages with the precision of the interferometer, while only requiring the interferometers be mounted on three sides of the stages. The principals of the present invention are further illustrated by the following example. This example describes one possible preferred embodiment for illustrative purposes only, the example does not limit the scope of the invention as set forth in the appended claims.

## EXAMPLE 1

The following example describes the sizing of the stages in an exemplary embodiment according to the present invention using equations (1)–(17). In this example, as illustrated in FIG. **3**, the X direction dimensions of the first and second stages are different, but the Y direction dimension of each is the same. One of skill in the art will understand that the present invention can be practiced with stage dimensions of infinite variety. This is due to the different potential ranges of values possible for each of the variables and the changes possible with the configurations of the stages, mirrors, and other elements. In particular, depending on a preferred orientation of interferometers, the Y direction dimension of either the first or second stage may be larger than that of the other stage in accordance with the teachings set forth herein.

The dimensions of first wafer stage **42** are now described with reference to FIGS. **4***a* and **4***b*. In FIG. **4***a*, wafer **6** is illustrated positioned on stage **42** and a projection on the stage of the exposure slit of the exposure apparatus is represented by outline **8**. As is known in the art, the X dimension of mirror **64** may be determined based on the wafer size and slit width, as well as certain other parameters as explained below. In this example, it is assumed that the stage **42** size is the same as the size of mirror **64** in the X direction. Also, in FIGS. **4**–**6**, **10**, and **11** the actual interferometer axes are depicted as thick lines, such as beam diameter **90** in FIG. **4***a*, while the virtual path of the interferometer is a thin dotted or solid line used in the remainder of the figures.

In an exemplary embodiment, as shown in FIGS. **4**–**7**, the predetermined parameters are:

| | |
|---|---|
| 300 mm | Wafer size (WS) 82 |
| 25 mm | Slit width (SW) 84 |
| 26.2 mm | Yaw separation (YS) 86 |
| 13.1 mm | Double path separation (DPS) 88 |
| 6 mm | Beam diameter (BD) 90 |
| 5 mm | Polishing margin (PM) 92 |
| 4 | n value chosen for New bow correction (NBC) |

The X direction mirror size may be determined by solving the following five equations:

Exposure area $(EA)$ **94**$=WS+SW$ Eq. (1)

$NBC=YS/n$ Eq. (2)

Integered exposure area $(IEA)$ **95**$=NBC*(Int(EA/NBC)+1)$ Eq. (3)

Additional length $(AL)$ **98**$=(YS/2+DPS/2+BD/2+PM)$ Eq. (4)

$X$ Mirror size $(XMS)$ **100**$=IEA+2*AL$ Eq. (5)

As shown in FIG. **4***b*, exposure area **94** is the area that is swept under projection lens focal point **72**. The X dimension of this area is determined by wafer size **82** and slit width **84** as Eq. (1) shows. Yaw separation **86** is the distance interferometer axes must be separated to accurately determine wafer stage **42** and **44** yaw. Integered exposure area **95** is based on yaw separation **86**, exposure area **94**, and NBC as shown in Eq. (3). For a discussion of the new bow correction, see U.S. Pat. No. 5,790,253, which describes the conventional method of correcting for curving deviations associated with mirror imperfections, and is incorporated by reference. In this conventional method, when measuring linearity errors of a moving mirror by means of a laser interferometer having two measuring length axes, the bow correction is made by shifting the moving mirror by less than yaw separation **86** and, therefore, the measurement points of the axes overlap. The decree of overlap is indicated by the denominator n. The linearity errors which indicate the curving of the reflecting surface of the moving mirror are then based on the relationship of adjacent measurement

values. New bow correction indicates the length of mirror necessary to perform the conventional method of correcting for mirror linearity errors. It is a function of YS 86 and an arbitrary denominator n, chosen by one of skill in the art based on the resolution of the deviation correction needed and interferometer accuracy. A higher value for n is chosen where higher resolution is needed. and, therefore, n is greater than or equal to one.

Additional length **98** is based on yaw separation **86**, double path separation **88**, beam diameter **90**, and polishing margin **92** as shown in Eq. (4). The X dimension of first wafer stage **42** is equal to its X mirror dimension and shown by Eq. (5) to be the sum of integered exposure area **95** and additional length **98** needed on each side of stage **42**. In this example, given the wafer size, slit width, and other fixed parameters, solving equations (1)–(5) produces a X dimension for mirror **42** of 382.8 mm.

Now referring to FIG. **5**, this X dimension then provides the basis for calculating the X direction separation of field image alignment area **74** and interferometer **48** from focal point **72** and interferometer **52** necessary to allow stages **42** and **44** to move in the Y direction. This is baseline separation **80** and it drives the X distance between interferometers **48** and **52**. Baseline separation **80** is 393 mm and is calculated:

$$\text{Baseline Separation } (BS)\ 80=\text{Stage } \mathbf{42}\ XMS-DPS+2*(YS-(DPS/2+BD/2)-PM) \quad \text{Eq. (6)}$$

Given a specific first wafer stage size, the size of second wafer stage **44** is also then calculated according to the invention. More specifically, the parameter of beam clearance **108**, the distance that an interferometer beam is designed to clear the wafer stage, is needed in addition to the predetermined parameters of FIG. **4***b*. Wafer stage **44** X mirror size may be determined by solving the following two equations:

$$\text{Beam clearance } (BC)=YS-PM-2*(DPS/2+BD/2) \quad \text{Eq. (7)}$$

$$\text{Stage 44 } XMS=\text{Stage } \mathbf{42}\ XMS+2*(DPS+BD+BC+PM) \quad \text{Eq. (8)}$$

Second wafer stage **44** is thus made greater than first wafer stage **42** with additions to its X dimension. Each of these additions is the sum of double path separation **88**, beam diameter **90**, beam clearance **108**, and polishing margin **92**. Again it is assumed that the stage **44** size is the same as the size of mirror **70** in the X direction. Thus, for the given first stage size and predetermined parameter values, solving equations (7) and (8) produces a second wafer stage **44** X dimension of 435.2 mm.

Wafer stages **42** and **44** are the same dimension in the Y direction. In the Y direction, stage size is not equated to mirror size, unlike the X direction in this example. Computation of the Y dimension requires the additional predetermined parameters of: maximum velocity, acceleration, settling time, X mirror thickness and slit length.

| For: | | | |
|---|---|---|---|
| | 375 | mm/sec | Maximum velocity |
| | 0.75 | g | Acceleration |
| | 50 | msec | Settling time |
| | 25 | mm | X mirror thickness (MT) 87 |
| | 9 | mm | Slit length (SL) 85 |

Y table size is computed using Equations (9)–(13). These equations that follow can best be understood by referring to FIG. **6**. Acceleration and deceleration area **104** is determined by the maximum acceleration and velocity of wafer stages **42**, **44** and the settling time required once the correct position has been reached, per Eq. (11). Interferometer length **96** is a function of yaw separation **86**, double path separation **88**, and beam diameter **90**; parameters previously discussed with reference to FIGS. **4***a*, **4***b*, and **5**. In this example, solving equations (9)–(13) gives a Y dimension of 435.9 mm.

$$\text{Exposure area } Y\ (EAY)\ 102=WS+SL \quad \text{Eq. (9)}$$

$$\text{Acceleration and deceleration area ("}Acc\text{") 104 ("}Acc\text{")}=[(\text{Maximum velocity}**2)/(2*\text{Acceleration})+(\text{Maximum velocity}*\text{Settling time})] \quad \text{Eq. (10)}$$

$$\text{Interferometer length ("}Inf\text{") 96 ("}Inf\text{")}=[YS/2+DPS/2+BD/2] \quad \text{Eq. (11)}$$

$$Y \text{ mirror size } (YMS)=EA+2*(Acc+Inf) \quad \text{Eq. (12)}$$

$$Y \text{ stage size}=YMS+MT \quad \text{Eq. (13)}$$

FIG. **7** illustrates the Y dimension needed for stages **42**, **44** to move without contacting each other within dual wafer stage assembly **40**. Interferometers and supporting structure are not shown in this diagram as this is a representation of the space necessary for the stages to move freely. The necessary distance is Y swept area **106**. Mechanical margin **112** is the parameter defining the clearance between stages as they pass each other and is 24 mm, as discussed within. Y swept area **106** is determined by equation (14) to be 895.8 mm, with the Y separation of interferometers **46** and **56**, or Y baseline dimension **89**, determined by equation (15) to be 150.9 mm.

$$Y \text{ swept area}=2*Y \text{ stage dimension}+\text{mechanical margin} \quad \text{Eq. (14)}$$

$$Y \text{ Baseline Dimension } (YBD)\ 89=2*(Acc+Inf)+MT \quad \text{Eq. (15)}$$

FIGS. **8** and **9** illustrate the X dimension needed for stages **42**, **44** to move without hindrance within dual wafer stage assembly **40**. X swept area **114** is the distance covered by second wafer stage **44** during the course of its movement. X swept area includes the space necessary for stage **44** to undergo field image alignment while stage **42** is being exposed, plus the baseline separation **80** of interferometers **48** and **52** (Eq. (6)), plus the area necessary for stage **44** to undergo exposure while stage **42** undergoes field image alignment. X swept area **114** is the sum of the X dimension of wafer stages **42**, twice the X dimension of second wafer stage **44** and mechanical margin **112** minus additional length **98** and baseline dimension **80** as shown in Eq. (16).

$$X \text{ swept area } 114=3*\text{wafer stage } \mathbf{42}\ XMS/2-AL+2*MM+2*\text{wafer stage } \mathbf{44}\ XMS-BS \quad \text{Eq. (16)}$$

FIG. **10** illustrates the reasons driving mechanical margin **112** to 24 mm which are described by Eq. (17). Interferometer **48***a* is a dual beam interferometer. For it to function both beams must be incident on the mirror, avoiding polishing margin **92** to ensure beam coherency. If mechanical margin **112** is greater than 24 mm then interferometer **48***a* cannot be used for measuring first wafer stage **42** position in the safety area as shown in FIG. **14**(*o*). Another interferometer axis would be required. A mechanical margin **112** of greater than 24 mm would result in one of the dual beams of interferometer **48** a hitting wafer stage **42** in the polishing margin **92**.

$$MM\ 112=WS/2+\text{Stage } \mathbf{44}\ XMS/2-DPS/2+BD/2-BS+PM \quad \text{Eq. (17)}$$

FIG. **11** illustrates the reason why interferometer **52** cannot cover first wafer stage **42** when it is in the loading position and interferometer **54** must be added. Wafer stage

42 must be covered by interferometer **48** when in the exposure position and nearest to wafer stage **44** while stage **44** is in the field image alignment position. Wafer stage **42** must also be covered by an interferometer while in the loading position. With interferometers **48** and **52** set at the baseline dimension **80** apart, and given mechanical margin **112**, the center of wafer stage **44** during loading is fixed along the axis of interferometer **54** as shown. The center of wafer stage **42** must therefore also be on this axis, as the loading positions for the wafers are the same. But given the smaller size of wafer stage **42**, when wafer stage **42** is in line for loading, interferometer **52** is too far from the center of wafer stage **42** to be functionally incident upon wafer stage **42**, thus making interferometer **54** necessary. The left beam of double-path interferometer **52** would not be reflected by the mirror on wafer stage **42** since it is shown by Eq. (18) to be 212.05 mm from the center of the loading position. This is further than half of the X dimension of wafer stage **42**, which is only 191.4 mm.

| | |
|---|---|
| Eq. (18) | Distance of interferometer 52 left beam from Wafer stage 44 center 91 = Wafer stage 44 XMS/2 − [BS − WS/2 − SW/2 − Wafer stage 42 XMS/2 − MM − DPS/2 − BD/2] = 212.05 mm |

FIG. **13**(*a*)–(*e*) is a flowchart of a preferred method for utilizing the dual wafer stage of the present invention. This flowchart illustrates a preferred method of utilizing dual wafer stage assembly **40** of the present invention. The flowchart further illustrates interferometer use during the movement of the stages. Individual steps in the flowchart are discussed in more detail in the referenced sub-illustrations of FIG. **3** and FIG. **14**(*a*)–(*v*).

Referring again to FIG. **13**(*a*), in step **200**, further illustrated by FIG. **14**(*a*), first wafer stage **42** is loading and its X position is controlled by interferometer **56*a*** changing to interferometer **56**, its Y position by interferometer **54**, and Yaw is controlled by interferometer **54**. Second wafer stage **44** is stopped to begin the exposure sequence if loaded with a wafer and its X position is controlled by interferometer **46**, its Y position **48**, and its Yaw by interferometer **48**.

In step **202**, further illustrated by FIG. **14**(*b*), first wafer stage **42** is starting enhanced global alignment and its X position is controlled by interferometer **56**, its Y position by interferometer **54** changing to interferometer **52**, and Yaw is controlled by interferometer **54** changing to interferometer **56**. At times stage **42** is halted to avoid disturbing the movement of stage **44**. Second wafer stage **44** is in the exposure sequence if loaded with a wafer and its X position is controlled by interferometer **46**, its Y position by interferometer **48**, and its Yaw by interferometer **48**.

In step **204**, further illustrated by FIG. **14**(*c*), first wafer stage **42** is in enhanced global alignment and its X position is controlled by interferometer **56**, its Y position by interferometer **52** changing to **50**, and Yaw is controlled by interferometer **56**. Second wafer stage **44** X is stopped at the end of the exposure sequence if loaded with a wafer and its position is controlled by interferometer **46**, its Y position by interferometer **48**, and its Yaw by interferometer **48**.

In step **206**, further illustrated by FIG. **14**(*d*), first wafer stage **42** has ended enhanced global alignment and is switching in the Y direction. Its X position is controlled by interferometer **56**, its Y position by **50**, and Yaw is controlled by interferometer **56** changing to interferometer **52** and **50**. Second wafer stage **44** is switching in the Y direction and its X position is controlled by interferometer **46**, its Y position by interferometer **48**, and its Yaw by interferometer **48**.

In step **208**, further illustrated by FIG. **14**(*e*), first wafer stage **42** is switching in the Y direction and its X position is controlled by interferometer **56*a***, its Y position by **50**, and Yaw is controlled by interferometer **52** and **50**. Second wafer stage **44** is waiting for interferometer **56*c*** to become available to control its X position and its Y position is controlled by interferometer **48**, and its Yaw by interferometer **48**.

In step **210**, further illustrated by FIG. **14**(*f*), first wafer stage **42** is waiting for interferometer **46** to become available to control its X position. Its Y position is controlled by interferometer **50**, and Yaw is controlled by interferometer **52**. Second wafer stage **44** is switching in the Y direction and its X position is controlled by interferometer **56*c***, its Y position by interferometer **48**, and its Yaw by interferometer **48**.

In step **212**, further illustrated by FIG. **14**(*g*), first wafer stage **42** is switching in the Y direction and its X position is controlled by interferometer **46**, its Y position by **50**, and Yaw is controlled by interferometer **46**. Second wafer stage **44** is switching in the Y direction and its X position is controlled by interferometer **56*c*** changing to interferometer **56**, its Y position by interferometer **48**, and its Yaw by interferometer **48** changing to interferometer **56**.

Now referring to FIG. **13**(*b*), in step **214**, further illustrated by FIG. **14**(*h*), first wafer stage **42** is switching in the X direction and its X position is controlled by interferometer **46**, its Y position by interferometer **52** changing to interferometer **48*c***, and Yaw is controlled by interferometer **46**. Second wafer stage **44** is waiting for stage **42** to finish moving. Its X position is controlled by interferometer **56**, its Y position by interferometer **48** changing to interferometer **48*a***, and its Yaw by interferometer **56**.

In step **216**, further illustrated by FIG. **14**(*i*), first wafer stage **42** is now stopped and waiting for stage **44** to finish moving. Its X position is controlled by interferometer **46**, its Y position by interferometer **48*c***, and Yaw is controlled by interferometer **46**. Second wafer stage **44** is switching in the X direction and its X position is controlled by interferometer **56**, its Y position by interferometer **48*a*** changing to interferometer **52**, and its Yaw by interferometer **56**.

In step **218**, further illustrated by FIG. **14**(*j*), first wafer stage **42** is starting the exposure sequence and its X position is controlled by interferometer **46**, its Y position by interferometer **48*c*** changing to interferometer **48**, and Yaw is controlled by interferometer **46**. Second wafer stage **44** is switching in the X direction and its X position is controlled by interferometer **56**, its Y position by interferometer **52** changing to interferometer **54**, and its Yaw by interferometer **56**.

In step **220**, further illustrated by FIG. **14**(*k*) (also known as FIG. **3**), first wafer stage **42** is starting the exposure sequence and its X position is controlled by interferometer **46**, its Y position by interferometer **48**, and Yaw is controlled by interferometer **46**. Second wafer stage **44** is loading or unloading and its X position is controlled by interferometer **56**, its Y position by interferometer **54**, and its Yaw by interferometer **56**.

In step **222**, further illustrated by FIG. **14**(*l*), first wafer stage **42** is in the exposure sequence and its X position is controlled by interferometer **46**, its Y position by interferometer **48**, and its Yaw by interferometer **46**. Second wafer stage **44** is still stopped and loading or unloading. Its X position is controlled by interferometer **56**, its Y position by interferometer **54** changing to interferometer **52**, and Yaw is controlled by interferometer **56**.

In step **224**, further illustrated by FIG. **14**(*m*), first wafer stage **42** is in the exposure sequence and its X position is

controlled by interferometer **46**, its Y position by interferometer **48**, and Yaw is controlled by interferometer **46**. Second wafer stage **44** is in enhanced global alignment and its X position is controlled by interferometer **56**, its Y position by interferometer **52**, and its Yaw by interferometer **56**.

In step **226**, further illustrated by FIG. **14**(*n*), first wafer stage **42** is ending the exposure sequence and its X position is controlled by interferometer **46**, its Y position by interferometer **48**, and Yaw is controlled by interferometer **46**. Second wafer stage **44** is in enhanced global alignment and its X position is controlled by interferometer **56**, its Y position by interferometer **52**, and its Yaw by interferometer **56**.

In step **228**, further illustrated by FIG. **14**(*o*), first wafer stage **42** is stopped in the safety position waiting for stage **44** to finish EGA and its X position is controlled by interferometer **46**, its Y position by interferometer **48***a*, and Yaw is controlled by interferometer **46**. Second wafer stage **44** is ending enhanced global alignment and its X position is controlled by interferometer **56**, its Y position by interferometer **52**, and its Yaw by interferometer **56**.

Now referring to FIG. **13**(*c*), in step **230**, further illustrated by FIG. **14**(*p*), first wafer stage **42** is stopped in the safety position and its X position is controlled by interferometer **46**, its Y position by interferometer **48***b*, and Yaw is controlled by interferometer **46**. Second wafer stage **44** is switching in the X direction and its X position is controlled by interferometer **56**, its Y position by interferometer **52**, and its Yaw by interferometer **56**.

In step **232**, further illustrated by FIG. **14**(*q*), first wafer stage **42** is switching in the X direction and its X position is controlled by interferometer **46**, its Y position by interferometer **48***b* changing to **50**, and Yaw is controlled by interferometer **46**. Second wafer stage **44** is waiting for interferometer **48***a* to become available and its X position is controlled by interferometer **56**, its Y position by interferometer **52**, and its Yaw by interferometer **56**.

In step **234**, further illustrated by FIG. **14**(*r*), first wafer stage **42** is switching in the X direction and its X position is controlled by interferometer **46**, its Y position by **50**, and Yaw is controlled by interferometer **46**. Second wafer stage **44** is waiting in the switch X/wait position and its X position is controlled by interferometer **56**, its Y position by interferometer **52** changing to interferometer **48***a*, and its Yaw by interferometer **56**.

In step **236**, further illustrated by FIG. **14**(*s*), first wafer stage **42** is switching in the X direction and its X position is controlled by interferometer **46**, its Y position by interferometer **50** changing to interferometer **52**, and Yaw is controlled by interferometer **46**. Second wafer stage **44** is in the waiting in the X direction and its X position is controlled by interferometer **56**, its Y position by interferometer **48***b* changing to interferometer **48**, and its Yaw by interferometer **56** changing to interferometer **48**.

In step **238**, further illustrated by FIG. **14**(*t*), first wafer stage **42** is switching in the X direction and its X position is controlled by interferometer **46**, its Y position by interferometer **52** changing to interferometer **54**, and Yaw is controlled by interferometer **46** changing to interferometer **54**. Second wafer stage **44** is waiting and its X position is controlled by interferometer **56**, its Y position by interferometer **48**, and its Yaw by interferometer **48**.

In step **240**, further illustrated by FIG. **14**(*u*), first wafer stage **42** is switching in the Y direction and its X position is controlled by interferometer **46** changing to interferometer **56***a*, its Y position by interferometer **54**, and Yaw is controlled by interferometer **54**. Second wafer stage **44** is switching in the Y direction and its X position is controlled by interferometer **56** changing to interferometer **56***c*, its Y position by interferometer **48**, and its Yaw by interferometer **48**.

Now referring to FIG. **13**(*d*), in step **242**, further illustrated by FIG. **14**(*v*), first wafer stage **42** is waiting in the switch Y/wait position before moving to the loading position and its X position is controlled by interferometer **56***a*, its Y position by interferometer **54**, and Yaw is controlled by interferometer **54**. Second wafer stage **44** is in position to begin the exposure sequence switching in the Y direction and its X position is controlled by interferometers **56***c* changing to interferometer **46**, its Y position by interferometer **48**, and its Yaw by interferometer **48**.

Step **243** is the decision block for whether to continue to process more wafers. Should the answer be "yes" the method returns to step **200** and continues in sequence, otherwise the method continues to step **244** which is also illustrated by FIG. **14**(*a*), except the actions taken account for the fact that wafer stage **42** is now empty.

In step **244**, further illustrated by FIG. **14**(*a*), first wafer stage **42** is unloaded but not reloaded. Its X position is controlled by interferometer **56***a* changing to interferometer **56**, its Y position by interferometer **54**, and Yaw is controlled by interferometer **54**. Second wafer stage **44** is stopped to begin the exposure sequence and its X position is controlled by interferometer **46**, its Y position by interferometer **48**, and its Yaw by interferometer **48**.

In step **246**, further illustrated by FIG. **14**(*b*), first wafer stage **42** X position is controlled by interferometer **56**, its Y position by interferometer **54** changing to interferometer **52**, and Yaw is controlled by interferometer **54** changing to interferometer **56**. At times stage **42** is halted to avoid disturbing the movement of stage **44**. Second wafer stage **44** is in the exposure sequence and its X position is controlled by interferometer **46**, its Y position by interferometer **48**, and its Yaw by interferometer **48**.

In step **248**, further illustrated by FIG. **14**(*c*), first wafer stage **42** X position is controlled by interferometer **56**, its Y position by interferometer **52** changing to **50**, and Yaw is controlled by interferometer **56**. Second wafer stage **44** is stopped at the end of the exposure sequence and its X position is controlled by interferometer **46**, its Y position by interferometer **48**, and its Yaw by interferometer **48**.

In step **250**, further illustrated by FIG. **14**(*d*), first wafer stage **42** is switching in the direction. Its X position is controlled by interferometer **56**, its Y position by **50**, and Yaw is controlled by interferometer **56** changing to interferometer **52** and **50**. Second wafer stage **44** is switching in the Y direction and its X position is controlled by interferometer **46**, its Y position by interferometer **48**, and its Yaw by interferometer **48**.

In step **252**, further illustrated by FIG. **14**(*e*), first wafer stage **42** is switching in the direction and its X position is controlled by interferometer **56***a*, its Y position by **50**, and Yaw is controlled by interferometer **52** and **50**. Second wafer stage **44** is waiting for interferometer **56***c* to become available to control its X position and its Y position is controlled by interferometer **48**, and its Yaw by interferometer **48**.

In step **254**, further illustrated by FIG. **14**(*f*), first wafer stage **42** is waiting for interferometer **46** to become available to control its X position. Its Y position is controlled by **50**, and Yaw is controlled by interferometer **52**. Second wafer stage **44** is switching in the Y direction and its X position is controlled by interferometer **56***c*, its Y position by interferometer **48**, and its Yaw by interferometer **48**.

In step **256**, further illustrated by FIG. **14**(*g*), first wafer stage **42** is switching in the Y direction and its X position is controlled by interferometer **46**, its Y position by **50**, and Yaw is controlled by interferometer **46**. Second wafer stage **44** is switching in the Y direction and its X position is controlled by interferometer **56***c* changing to interferometer **56**, its Y position by interferometer **48**, and its Yaw by interferometer **48** changing to interferometer **56**.

In step **258**, further illustrated by FIG. **14**(*h*), first wafer stage **42** is switching in the X direction and its X position is controlled by interferometer **46**, its Y position by interferometer **52** changing to interferometer **48***c*, and Yaw is controlled by interferometer **46**. Second wafer stage **44** is waiting for stage **42** to finish moving. Its X position is controlled by interferometer **56**, its Y position by interferometer **48** changing to interferometer **48***b*, and its Yaw by interferometer **56**.

In step **260**, further illustrated by FIG. **14**(*i*), first wafer stage **42** is now stopped and waiting for stage **44** to finish moving. Its X position is controlled by interferometer **46**, its Y position by interferometer **48***c*, and Yaw is controlled by interferometer **46**. Second wafer stage **44** is switching in the X direction and its X position is controlled by interferometer **56**, its Y position by interferometer **48***a* changing to interferometer **52**, and its Yaw by interferometer **56**.

In step **262**, further illustrated by FIG. **14**(*j*), first wafer stage **42** is not beginning the exposure sequence since it was not loaded. Its X position is controlled by interferometer **46**, its Y position by interferometer **48***c* changing to interferometer **48**, and Yaw is controlled by interferometer **46**. Second wafer stage **44** is unloading X position is controlled by interferometer **46**, its Y position by interferometer **48**, and its Yaw by interferometer **48**. The unloading of second wafer stage **44** ends the method.

The use of the exposure apparatus and dual wafer stage assembly described herein is not limited to a lithography system for semiconductor manufacturing. This arrangement may be employed advantageously in other assemblies wherein objects other than wafers must be precisely positioned while they are processed simultaneously. The apparatus, for example, can be used as an LCD lithography system that exposes a liquid crystal display device pattern onto a rectangular glass plate or a lithography system for manufacturing a thin film magnetic head. Furthermore, the exposure apparatus and dual wafer stage assembly can also be applied to a proximity lithography system that exposes a reticle pattern by closely locating a reticle and a substrate without the use of a lens assembly. Additionally, an exposure apparatus utilizing a dual wafer stage assembly according to the invention can be used in other devices, including other semiconductor processing equipment, machine tools, metal cutting machines, and inspection machines.

It is to be understood that while illustrative embodiments of the invention have been shown and described herein, various changes and adaptions in accordance with the teachings of the invention will be apparent to those of skill in the art. Such changes and adaptions nevertheless are included within the spirit and scope of the invention as defined in the following claims.

I claim:

**1**. A dual wafer stage assembly, comprising:

a base;

a first stage movable in a plane on said base to a series of first positions;

a second stage movable in said plane on said base to a series of second positions, where said first positions and said second positions are coextensive;

a plurality of interferometers mounted on said base with a corresponding plurality of moveable mirrors mounted on said first stage and said second stage wherein said interferometers, said first and said second stages, and said moveable mirrors are configured and dimensioned to allow for continuous determination of a position of each said stage at any position even where said first stage eclipses said second stage with respect to at least one of said plurality of interferometers.

**2**. A dual wafer stage assembly according to claim **1**, wherein said first and said second stages differ in dimension when measured in the direction perpendicular to said plane.

**3**. A dual wafer stage assembly according to claim **1**, wherein said first and said second stages differ in at least one dimension in said plane.

**4**. A dual wafer stage assembly according to claim **1**, claim **2**, or claim **3**, wherein a first said moveable mirror on said first stage and a second said moveable mirror on said second stage reflect alternatively to a common subset of said plurality of interferometers and where said second moveable mirror is larger than said first moveable mirror in at least one dimension such that a region is created where said second moveable mirror is larger than said first moveable mirror and where at least one of said plurality of interferometers utilizes said region in the continuous determination of the position of said second stage.

**5**. A dual wafer stage assembly according to claim **4**, wherein said second stage and said second moveable mirror are the same dimensions in the plane of said second moveable mirror.

**6**. A dual wafer stage assembly according to claim **4**, wherein said second moveable mirror is sectioned with at least one of said sections offset from the other said section in the direction parallel to the axes of said subset of interferometers.

**7**. A dual wafer stage assembly according to claim **6**, wherein said second moveable mirror is sectioned such that one of said sections is approximately the same dimensions as said stage supporting said section.

**8**. A dual stage assembly, comprising:

a base;

a plurality of interferometers mounted on said base for determination of stage positions, said interferometers each including at least one interferometer axis directed towards a moveable mirror;

a first stage moveable in a plane between multiple positions on said base and having at least a first moveable mirror mounted thereon; and

a second stage moveable in said plane between multiple positions on said base and having at least a second moveable mirror mounted thereon, said first and second stages being moveable to positions wherein the first stage eclipses the second stage with respect to said at least one said interferometer;

wherein said first and second moveable mirrors are configured to reflect to a common subset of interferometer axes, said second moveable mirror having a reflecting surface that cooperates with said interferometers in said eclipsing positions such that the position of said second stage is continuously determinable.

**9**. A dual stage assembly according to claim **8**, wherein said first moveable mirror's reflecting surface eclipses said first stage from said common subset of interferometers.

**10**. A dual stage assembly according to claim **9**, wherein said second moveable mirror's reflecting surface eclipses said second stage from said common subset of interferometers.

11. A dual wafer stage assembly according to claim **8**, wherein the reflecting surface of at least one of said moveable mirrors is comprised of sections.

12. A dual wafer stage assembly according to claim **8**, wherein the reflecting surface of at least one of said moveable minors is comprised of sections and at least one of said sections is not co-planar with the remaining sections.

13. A dual wafer stage assembly according to claim **8**, wherein said second moveable mirror extends beyond said second stage along the dimension defined by the intersection of the plane of said mirror and the plane of said stage.

14. A dual wafer stage assembly, comprising:
- a base;
- a first stage movable in a plane on said base;
- a second stage movable in said plane on said base; and
- a plurality of interferometers mounted along one side of said base which are directed to a first moveable minor mounted on said first stage and a second moveable minor mounted on said second stage where said plurality of interferometers and moveable mirrors cooperate to continuously determine the position of both said stages such that if said first stage is interposed between second said stage and at least one of said interferometers said second stage position is determined by at least one other of said interferometers.

15. A dual wafer stage assembly according to claim **14**, wherein said second moveable minor is larger than said first moveable minor in a dimension of said mirrors' reflecting surface.

16. A dual wafer stage assembly according to claim **15**, wherein said second stage and said second moveable minor's reflecting surface are of approximately the same dimensions.

17. A dual wafer stage assembly according to claim **14**, further comprising:
- a second plurality of interferometers are mounted along a second side of said base where said second side is perpendicular to said first side of said base;
- a third moveable minor mounted on said first stage and a fourth moveable minor mounted on said second stage where said second plurality of interferometers and said third and said fourth moveable minors cooperate to continuously determine the position of both said stages such that if said first stage is interposed between second said stage and at least one of said second plurality of interferometers said second stage position is determined by at least one other of said second plurality of interferometers.

18. A dual wafer stage assembly, comprising:
- a base;
- a first stage movable in a plane on said base;
- a second stage movable in said plane on said base wherein said second stage is larger than said first stage in at least one dimension of said plane; and
- a plurality of interferometers and moveable mirrors wherein said interferometers are mounted on said base and said moveable mirrors are mounted on said first and said second stages and said interferometers and said moveable mirrors are configured to facilitate the continuous determination of the positions of said stages, and where one or more portions of said moveable mirrors mounted on said second stage are located on said second stage where said second stage is larger than said first stage.

19. A method of utilizing a dual stage assembly where stage position is determined using interferometers, the method comprising:
- sizing a first stage and a second stage based on a determined size and exposure apparatus parameters;
- providing a plurality of interferometers directed in parallel at said stages and dispersed along one side of an area in which said stages will travel such that each of said stages' positions intersect an axis created by at least one of said plurality of interferometers at all times during the movement of said stages;
- equipping said first stage with a first movable mirror dimensioned to allow said interferometers to determine said first stage's position in a first desired direction;
- equipping said second stage with a second movable mirror dimensioned to allow at least one of said plurality of interferometers to determine said second stage's position in said first desired direction even if said first stage should be positioned between said second stage and said dispersed interferometers;
- moving said first and said second stages in said area; and
- determining said first stage's position and said second stage's position in said first direction using at least one of said plurality of interferometers for each of said stages' positions at all times.

20. A method of utilizing a dual stage assembly where stage position is determined using interferometers according to claim **19**, the method further comprising:
- providing at least one first orthogonal interferometer directed at said stages from a second side of said area and directed orthogonally to said first plurality of interferometers;
- providing at least one second orthogonal interferometer directed at said stages from a third side of said area and directed orthogonally to said first plurality of interferometers and directed parallel to said at least one first orthogonal interferometer;
- equipping said first stage with a third moveable mirror and said second stage with a fourth moveable mirror, said third and fourth mirrors configured and dimensioned to reflect to said at least one first orthogonal interferometer;
- equipping said first stage with a fifth moveable mirror and said second stage with a sixth moveable mirror, said fifth and sixth mirrors configured and dimensioned to reflect to said at least one second orthogonal interferometer, said at least one first orthogonal interferometer and said at least one second orthogonal interferometer and said third, fourth, fifth, and sixth moveable mirrors configured to determine said first and said second stages' positions in said orthogonal direction at all times during said stages' movement; and
- determining said first stage's position and said second stage's position in said orthogonal direction at all times during said movement using said orthogonal interferometers.

21. An exposure apparatus that forms an image on a substrate, comprising:
- a base;
- a first operation area comprising a first optical device that performs a first operation on a first substrate;
- a second operation area being adjacent to the first operational area, the second operational area comprising a second optical device that performs a second operation on a second substrate, the second substrate having previously had the first operation performed on the second substrate in the first operation area;
- a stage system comprising a first stage and a second stage, the first and the second stages holding one of the first

substrate and the second substrate and being movable on the base between the first operation area and the second operation area, respectively; and

an interferometer system including a plurality of interferometers, the interferometer system constantly monitoring the position of the each of the first stage and the second stage at all times during the movement of the each stage from the second operation area to the first operation area

wherein each stage that moves from the second operation area to the first operation area holds the second substrate that has had the second operation performed thereon in the second operation area.

**22**. The exposure apparatus of claim **21** wherein the interferometer system constantly monitoring the position of the each of the first stage and the second stage at all times during the movement of the each stage from the first operation area to the second operation area.

**23**. The exposure apparatus of claim **21** wherein the second operation area performs the second operation on the second substrate while the first operation area performs the first operation on the first substrate.

**24**. The exposure apparatus of claim **21** wherein the interferometer system monitors the position of the each of the first stage and the second stage in a first direction and a second direction that is perpendicular to the first direction respectively, and the first operation area and the second operation area are disposed with offset between each other in the first direction.

**25**. The exposure apparatus of claim **24** wherein the each of the first and the second stage has at least three mirrors that interact with the interferometer system respectively, a first mirror, a second mirror, and a third mirror are disposed on the first stage and fourth mirror, fifth mirror, and a sixth mirror are disposed on the second stage, wherein

the reflect surfaces of the first, third, fourth, and sixth mirrors face the first direction and the reflect surfaces of the second and fifth mirrors face the second direction.

**26**. The exposure apparatus of claim **24** wherein the first operation area and the second operation area are disposed with offset between each other in the second direction.

**27**. The exposure apparatus of claim **21**, wherein the second substrate that has had the second operation performed thereon in the second operation area is unloaded from each stage in the first operation area.

**28**. The exposure apparatus of claim **27**, wherein the first substrate for the first operation is loaded onto one of the first and second stages in the first operation area.

* * * * *

UNITED STATES PATENT AND TRADEMARK OFFICE

# CERTIFICATE OF CORRECTION

PATENT NO. : 6,785,005 B2
DATED : August 31, 2004
INVENTOR(S) : Fuyuhiko Inoue



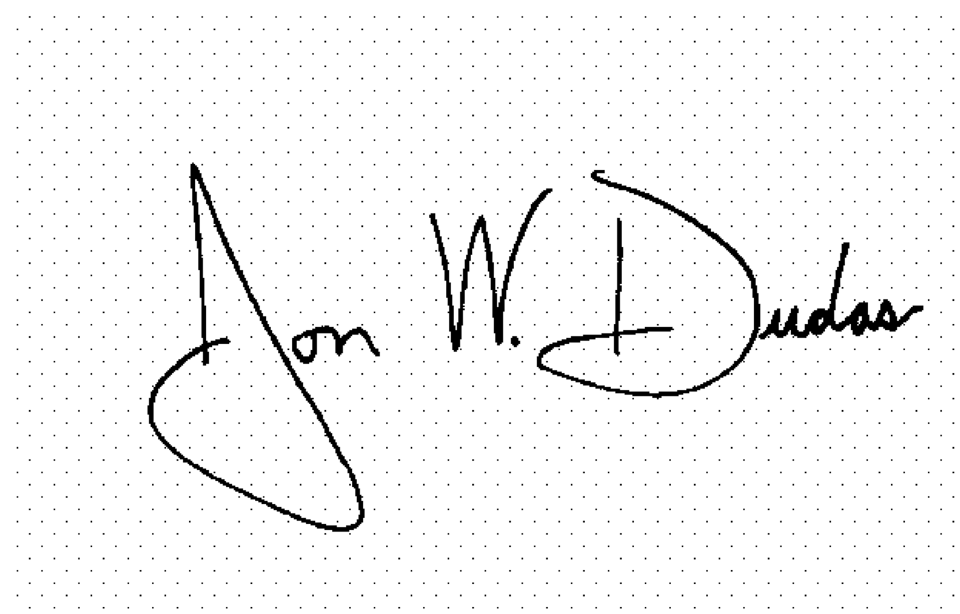
It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

Column 15,
Lines 6 and 42, delete “minors” and insert -- mirrors --.
Lines 17, 19, 27, 28, 39 and 40, delete “minor” and insert -- mirror --.
Line 32, delete “minor’s” and insert -- mirrors --.

Column 17,
Line 9, after “area”, insert -- , --.

Signed and Sealed this

Seventh Day of December, 2004



JON W. DUDAS
*Director of the United States Patent and Trademark Office*